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ABSTRACT

This packet of instructional materials is designed to give social science students in grades 6-9 a first-hand experience in working out solutions to real-life problems involving the management of California's water. Students work in groups on one of three problems presented in the packet: (1) the management of the Sacramento-San Joaquin Delta that empties into the San Francisco Bay; (2) the clean-up of the Kesterson Reservoir; and (3) the cut-back of water resources that California receives from rights to water from the Colorado River. Each student in the group is given a specific role to play in the problem, fact sheets with background information about their controversy, a list of players, details about the role they are to assume, and research questions relevant to the problem. After the research is completed, students work together to find a solution to the problem. Additional resources include a California Water Map to familiarize students with California's water geography; a chart indicating California's water system; a Colorado River Water Map; a Layperson's Guide to the Colorado River; a Layperson's Guide to the Delta; a Layperson's Guide to Agricultural Drainage; a vocabulary list; and a bibliography of 40 references of books, reference resources, videos, and other materials related to the topic. The maps are poster-size and have not been reproduced by ERIC. (MDH)

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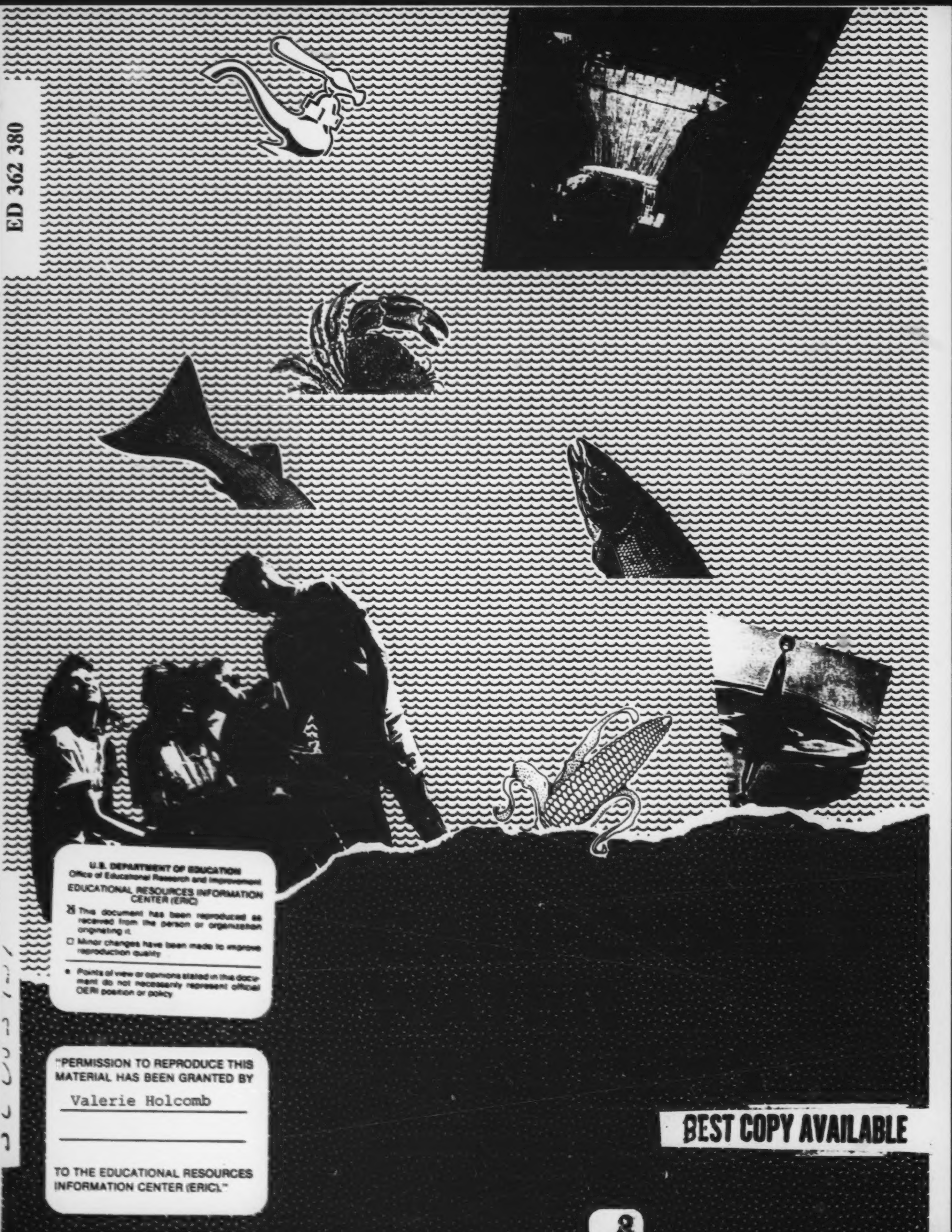

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Central Valley Project Water Association
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The Water Education Foundation's booklet included in this packet may be duplicated by teachers

The Water Education Foundation is a non-profit, tax-exempt organization. Its mission is to broaden public understanding of current water resource issues by fairly and accurately presenting information and the views of responsible persons and organizations

1989

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TEACHER INTRODUCTION

California has lived up to the Mark Twain maxim: "Whiskey is for drinking. Water is for fighting." Dating back to when the padres irritated the Indians by diverting streams to irrigate mission lands and to the 49ers' arguments over sloughs for their sluice boxes, water has been a focal point for controversy in California.

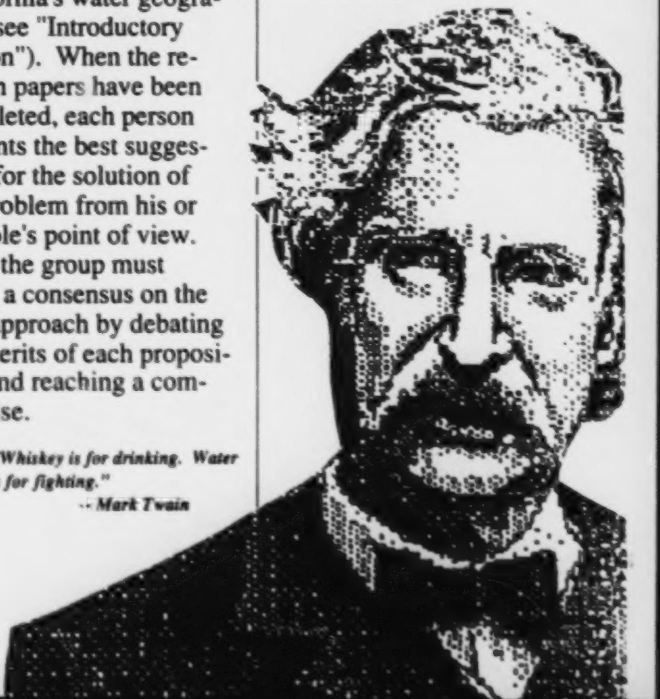
In the three scenarios in this program, students will get first-hand experience trying to work out a solution to a real-life problem involving the management of California's water. The class may be divided into two or three small groups. The groups may work on the same controversy or a different controversy in the set. Each student in the group will be given a role to play. Students will receive fact sheets with background information about their controversy, a list of the players, and details about the role they are to assume. Then the teacher can give them one or more problems to work on and suggestions about how to get more in-depth information. Students will be expected to research and write a short report on a specific topic that will prepare them for their parts in the discussion. The research topics are listed at the end of each player description.

Approximately a week should be allowed for students to write their research papers. During this time, the teacher should use some class time to conduct a lesson on the California Water Map to familiarize students with California's water geography (see "Introductory Lesson"). When the research papers have been completed, each person presents the best suggestion for the solution of the problem from his or her role's point of view. Then the group must reach a consensus on the best approach by debating the merits of each proposition and reaching a compromise.

"Whiskey is for drinking. Water is for fighting."
-- Mark Twain

This material is structured to comply with the curriculum organization established by the state history/social science framework. This cooperative learning exercise meets the need expressed in the framework for real life problem solving strategies.

The teacher should make the students aware that these water issues continue to be problems debated throughout California. For this reason, some of the information will be established fact, while other material will be still open to debate. Encourage students to think about the source of reference material and whether or not it is likely to contain a bias.



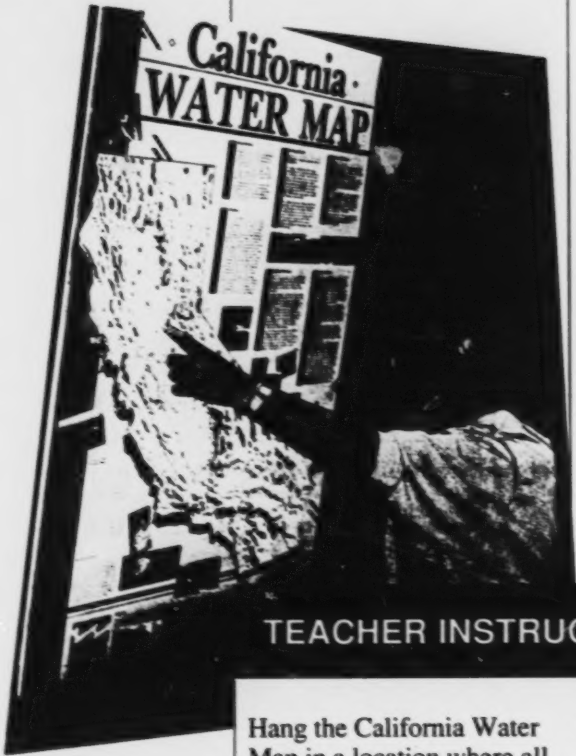
INTRODUCTORY LESSON

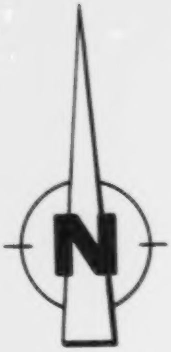
The California Water Map

OBJECTIVES

Students will be able to:

1. **Explain the relationship of California's geography to its water supply.**
2. **Trace the drainage pattern of rivers in the Central Valley.**
3. **Be able to use the text, scale, and legend of the map to obtain useful information.**





TEACHER INSTRUCTIONS

Hang the California Water Map in a location where all students can observe it. The following questions (with answers in parentheses) are meant to be only a guide for discussion.

What do the different colored lines indicate?

(Water courses like rivers and canals. Have a student identify the meaning of the different colors.)

Where do most rivers in California start?

(In the mountains)

Most of the rivers in California drain into one large area, what is it?

(The Central Valley)

What are the two main rivers which run north and south?

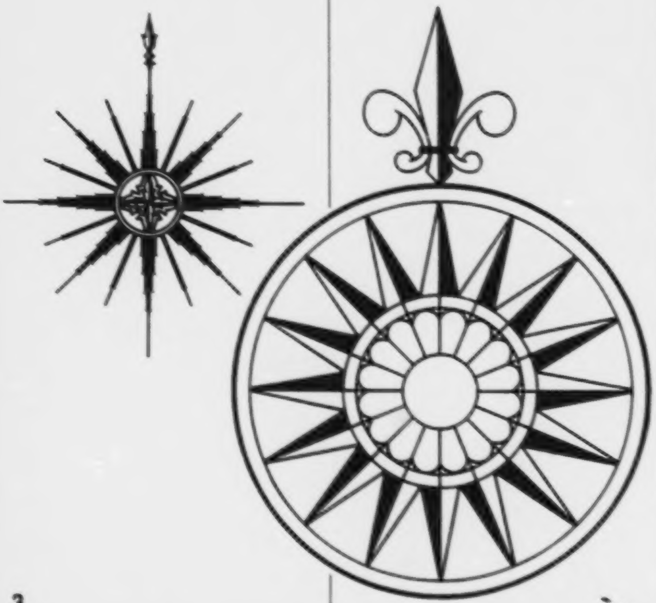
(The Sacramento and San Joaquin Rivers)

What area do these two rivers drain into?

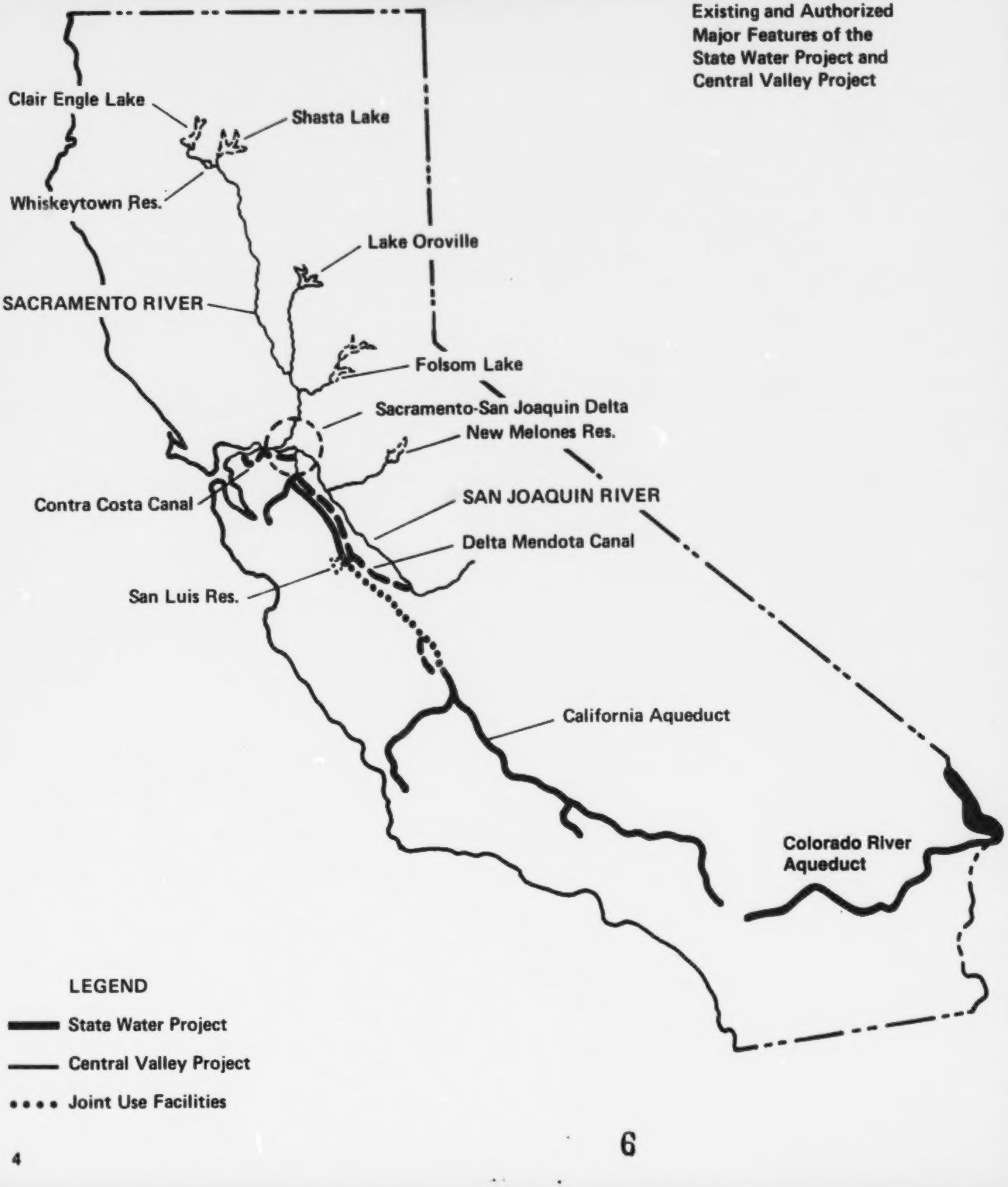
(The Sacramento-San Joaquin Delta)

About seventy-five percent of the rain and snow in California falls in the northern part of the state, but over seventy-five percent of the people live in the southern part of California. How is water moved to the places it is needed?

(In aqueducts and canals)



THE CALIFORNIA WATER MAP



Existing and Authorized Major Features of the State Water Project and Central Valley Project

Clair Engle Lake
Shasta Lake
Whiskeytown Res.
Lake Oroville
SACRAMENTO RIVER
Folsom Lake
Sacramento-San Joaquin Delta
New Melones Res.
Contra Costa Canal
SAN JOAQUIN RIVER
Delta Mendota Canal
San Luis Res.
California Aqueduct
Colorado River Aqueduct
LEGEND
State Water Project
Central Valley Project
•••• Joint Use Facilities

WORKSHEET FOR THE CALIFORNIA WATER MAP

The following worksheet can be assigned as group or individual class work.

1. **List the sources of water shown on the map that are within 50 miles of your school.**

2. **What federal water source is nearest your school?**

3. **Locate the Sacramento-San Joaquin Delta and describe where it begins and ends.**

4. **How many of California's rivers are classified "Wild and Scenic?"**

5. **What is the largest reservoir in the State Water Project (SWP) system?**

6. **Trace the path of water from the northernmost part of the SWP to the southern end.**

7. **What California industry is the single largest user of California's developed water? What percent is this of the state's total water runoff?**

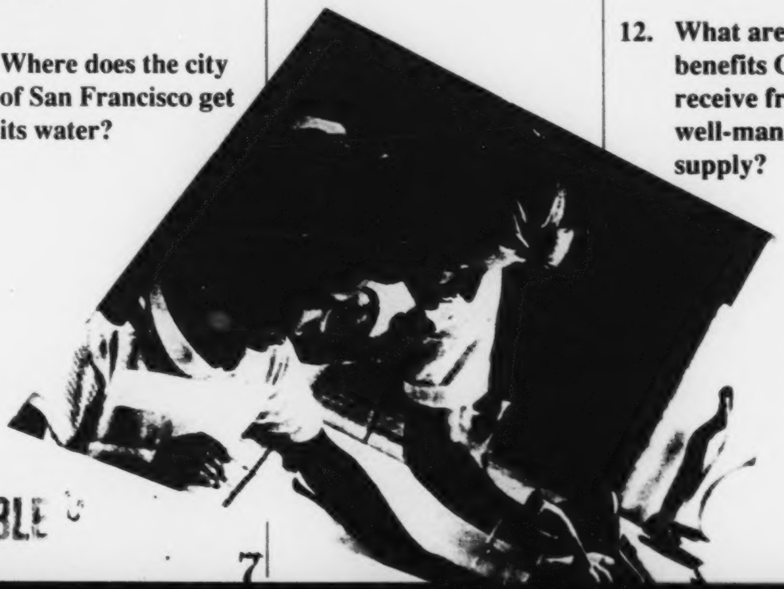
8. **The Sacramento-San Joaquin Valley and the Imperial Valley are two major agricultural areas in California. How do their water sources differ?**

9. **Where does the city of San Francisco get its water?**

10. **What water source do San Diego and the Imperial Valley have in common?**

11. **How far does the Owens Valley water flow from its source to Los Angeles?**

12. **What are some benefits Californians receive from our well-managed water supply?**



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ANSWERS TO THE CALIFORNIA WATER MAP WORKSHEET

1. Answers will vary.

2. Answers will vary.

3. The Sacramento-San Joaquin Delta begins where the Sacramento River branches out north and east of San Francisco and ends south of Stockton. It empties into San Francisco Bay.

4. There are ten wild and scenic rivers in California: all of the Smith, parts of the Klamath, Trinity, Van Duzen, Scott, Eel, Salmon, Feather, American and Tuolumne Rivers.

5. The largest reservoir in the SWP is Lake Oroville.

6. The SWP flows from Lake Oroville south through the Feather River to the Sacramento, through the Sacramento-San Joaquin Delta, splits to form the South Bay Aqueduct and the California Aqueduct which terminates at Lake Perris east of Los Angeles.

7. The largest user of California's developed water (in canals and reservoirs behind dams) is agriculture (85%). Agriculture uses 31% of the state's total runoff.

8. The Sacramento-San Joaquin Valley is richly supplied with water from many rivers draining into the valley. The Imperial Valley must import water from the Colorado River.

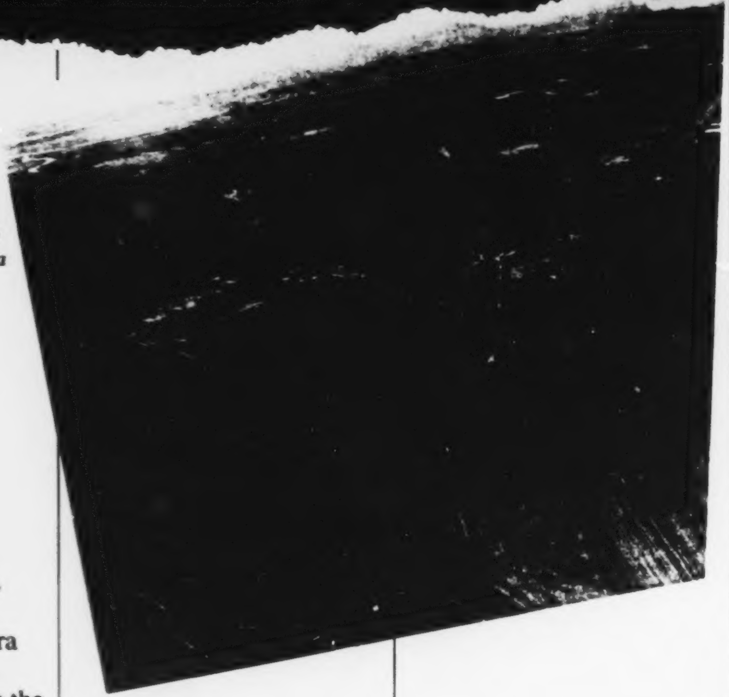
9. San Francisco gets its water from the Hetch Hetchy Reservoir in the Sierra via the Hetch Hetchy Aqueduct.

10. San Diego and the Imperial Valley both get water from the Colorado River.

11. The Los Angeles Aqueduct is approximately 240 miles long.

12. Californians benefit by having water managed for: irrigation, flood control, fish and wildlife support, improvement of navigational waterways, drinking water, water quality control, recreational opportunities, generation of clean hydroelectric power.

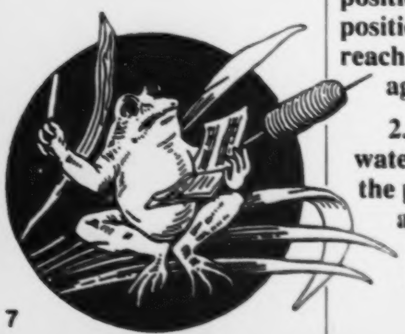
PART I - THE DELTA DILEMMA



Aerial view of the San Joaquin Delta

Flowing south, fed by the northern Sierra Nevada, the Sacramento River meets the northbound San Joaquin River to form the Sacramento-San Joaquin Delta in the Central Valley. The two rivers mingle with smaller rivers to form a 700-mile-long maze of rivers and sloughs surrounding 57 islands, many of them agricultural.

Their combined fresh water flows then roll on through the Carquinez Strait, a narrow break in the Coast Ranges, and on into San Francisco Bay's northern arm. Suisun Marsh and adjoining bays are the brackish transition between the freshwater flowing from the rivers and the salt water of the Bay.



The area has always been at the mercy of river flows and tides. Even before humans changed the Delta environment, salty ocean water from San Francisco Bay crept up Delta channels during dry summers, when mountain runoff slowed down. Then, during the winter, heavy runoff from the mountains kept the sea water out of the Delta. Upstream dams, including giant Shasta, help control this problem today.

OBJECTIVES

Students will be able to:

1. Collect information about the problem, organize it, state their position, listen to the positions of others, and reach a compromise agreement.

2. Conclude that water is a resource of all the people of California and must be managed for the benefit of all.

3. Discover that decisions about the environment are difficult and that many viewpoints and interests must be considered.

4. Describe the complex environment of an estuary.

5. Explain where the water in their community comes from.

6. Describe how toxic pollutants endanger California's water supply.

The Delta, as we know it, is largely a human invention. Early explorers found a vast mosquito-infested tidal marshland covered with bullrushes called tules. Later, trappers took advantage of the abundant wildlife. They were followed by farmers, some of them unsuccessful gold-seekers, who discovered wealth of another sort: fertile soil. Progressively higher levees were built to keep the surrounding waters out, lands were pumped dry, and what once was uncontrolled marshland was transformed into productive farmland.

Continued

THE DELTA DILEMMA

No other single area is quite as crucial to the state's overall water picture as the Delta - it forms the cornerstone of California's two largest water projects. Its existing channels are used to transport water to the federal and state pumps in the southern Delta. From there water is channeled south and west through canals and aqueducts to the south Bay area, agriculture-rich San Joaquin Valley and an estimated 18 million urban Californians, mostly in Southern California.

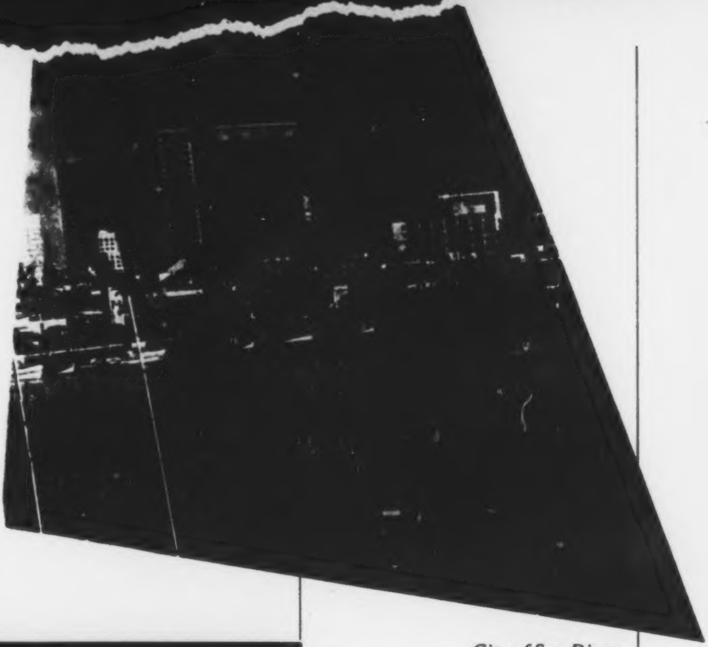
Water also flows west through the Delta and San Francisco Bay to the ocean, holding back the salt waters of the Bay and protecting water quality for consumption, recreation, and fish and wildlife. With brackish marshes and San Francisco Bay, the Delta forms part of an estuary and an important habitat for millions of migrating wildfowl, fish and other fauna and flora.

The Delta has gained considerable notoriety over the years as conflicting geographic areas and interests vie for more water. Setting quality and flow standards for the Delta and issuing water right permits have been ongoing responsibilities of the State Water Resources Control Board (SWRCB). As knowledge and understanding of this complex region have increased, these decisions have been challenged, updated, and amended. For several years, starting in 1987, the SWRCB will be conducting hearings to deal with problems exactly like the ones proposed in this unit.

THE PLAYERS

1. **Director of the California Department of Water Resources**
2. **Regional Director of the U.S. Bureau of Reclamation**
3. **Director of the California Department of Fish and Game**
4. **General Manager of the Metropolitan Water District of Southern California**
5. **General Manager of the State Water Contractors**
6. **Manager of the Kern County Water Agency**
7. **Senior Researcher for the Bay Institute of San Francisco**
8. **Attorney for the Environmental Defense Fund**
9. **Director for the Central Valley Project Water Users Association**

Recreation in the Delta



City of San Diego uses Delta water

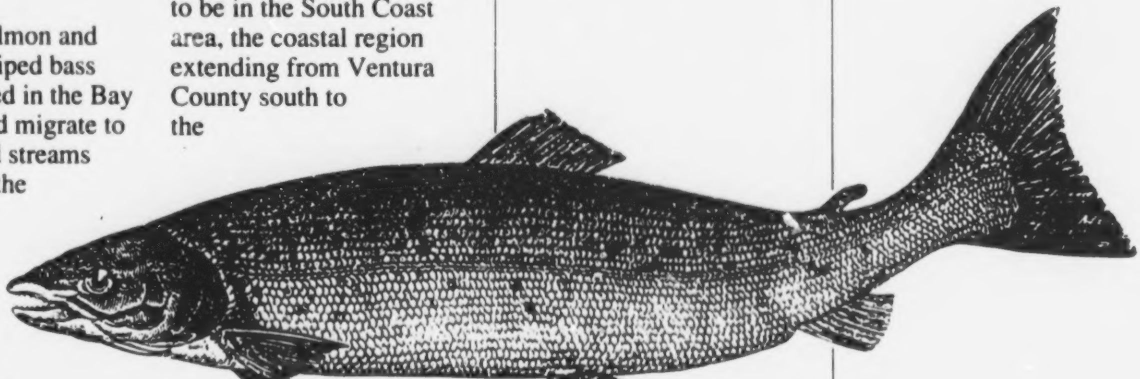
Tomatoes grown with Delta water in the San Joaquin Valley

THE PROBLEMS

1 How much more of the water flowing into the Delta could be diverted for agriculture, for instance into Kern County, which produces over $1.6 billion yearly?

2 Salmon and striped bass feed in the Bay and migrate to the rivers and streams flowing into the Delta to spawn. What was once a $7.5 million sportfishing industry in the 1960's is now greatly reduced. Scientists are unsure whether it is pollution or water diversion that is responsible for the loss of young fish. What can be done?

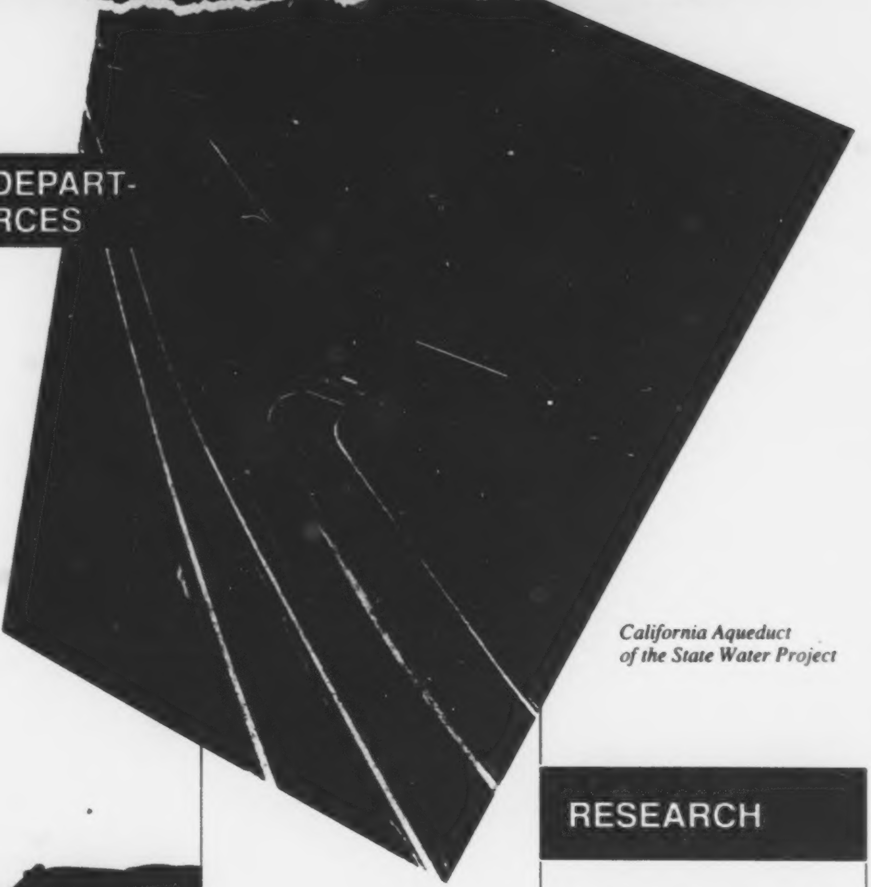
3 The Department of Water Resources estimates that the population of California will climb from the present 28 million to over 36 million by 2010. Over five million more people are expected to be in the South Coast area, the coastal region extending from Ventura County south to the Mexican Border. This area is expected to require over 604,000 additional acre-feet of water to meet the needs of its expanding population. Where will this extra water come from?



THE DELTA DILEMMA

DIRECTOR, CALIFORNIA DEPARTMENT OF WATER RESOURCES

The California Department of Water Resources (DWR) serves two principal functions: statewide water planning, and developing and managing the State Water Project (SWP). The Director's job is to balance the needs of the different areas of the state. DWR feels there will be an increasing demand for water, both above and below the Delta, for urban use and to correct groundwater overdraft. In general, DWR is opposed to increasing the flow of water out through the Bay because less water would be available in SWP service areas. The Director must also plan for future state water needs.



California Aqueduct of the State Water Project

RESEARCH

The State Water Project

How large is it? Where are its reservoirs? How much water do they hold? Who does the SWP supply with water? How much? How does the water get to the service areas? How is the water divided up? Are there laws about this?

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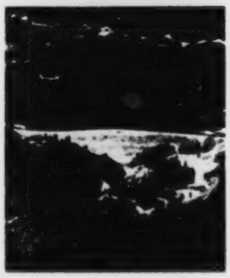
REGIONAL DIRECTOR, U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION

The Bureau of Reclamation oversees the functions of the federal Central Valley Project (CVP). The CVP supplies over 7 million acre-feet of water to farmers both above the Delta and below it in the Central Valley. The Bureau now has about one million acre-feet of extra water available, but has requests for over four times that amount from wildlife, agricultural, municipal and industrial water users. The Bureau is also interested in maintaining water quality. Its primary customer is agriculture, but the Bureau is moving toward more involvement with urban users. The Regional Director would like to see that all beneficial uses of California's water are balanced: agricultural, urban, industrial and environmental.

Shasta Dam at the top of the Central Valley

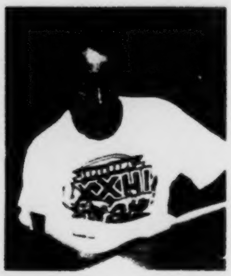


Whiskeytown Dam on the Trinity River

RESEARCH

The Central Valley Project

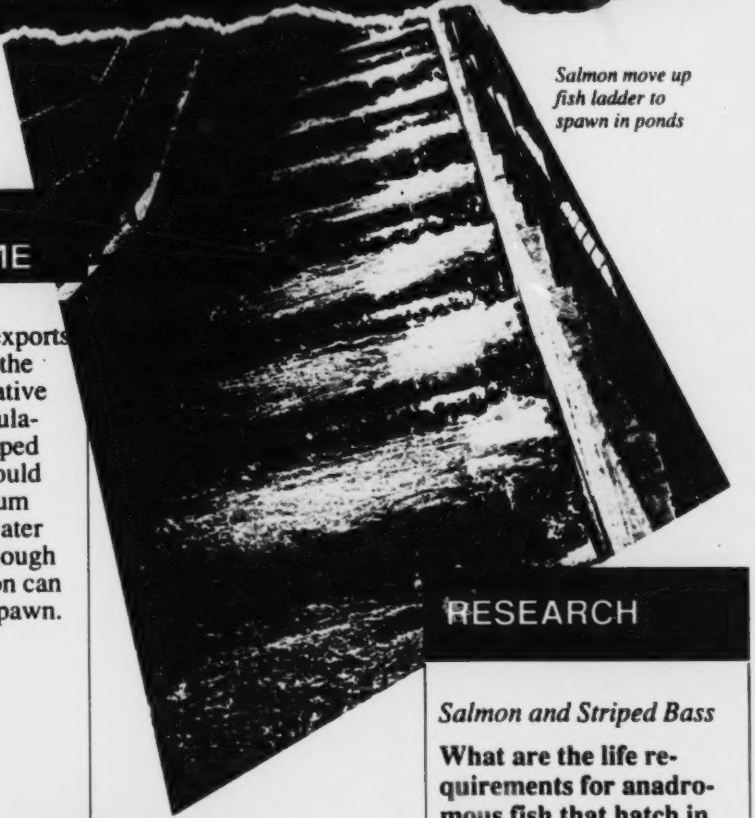
What is it? Where are its dams and reservoirs? How much water do they store? Who is entitled to buy this water? How do the rates for CVP water differ from SWP water? How does the water get to the buyers? How much water is currently being supplied?



Delta Cross Channel helps move water in the Delta

DIRECTOR, CALIFORNIA DEPARTMENT OF FISH AND GAME

The job of the Department of Fish and Game (DFG) is to protect the wildlife of California and their habitats. The Director hopes that the SWRCB will find that it is in the public interest to protect fish and wildlife from certain adverse effects of water development. DFG believes beneficial uses of the Delta's water, including providing a good environment for fish and wildlife, should be given a higher priority than exporting Delta water for other purposes. DFG also believes that increased water exports at critical times from the Delta have had a negative influence on fish populations, particularly striped bass. The Director would like to see the minimum spring and summer water flows be kept high enough so the bass and salmon can swim upstream and spawn.

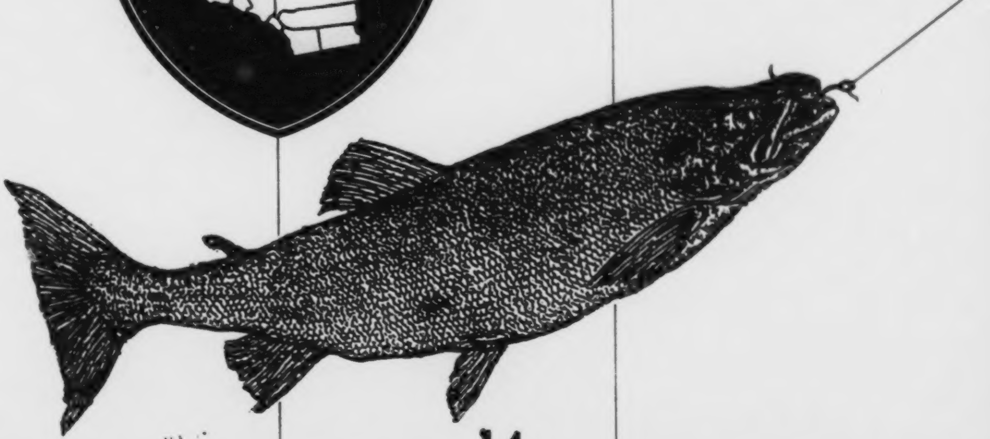


Salmon move up fish ladder to spawn in ponds

RESEARCH

Salmon and Striped Bass

What are the life requirements for anadromous fish that hatch in fresh water, swim downstream and out to sea, and then return to the streams where they were spawned to reproduce? How do reverse flows in the Delta affect fish? What do fish screens at the pumping plants do?



GENERAL MANAGER METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

The Metropolitan Water District of Southern California (MWD) is the major water supplier of the urban and industrial areas on the southern coastal area of the state. Its service area includes over 13 million people and its sales of water imported mostly from the Colorado River and the SWP total nearly $250 billion annually. MWD estimates the population of its service area is expanding at the rate of 180,000 people a year. The area's needs are increasing and MWD is working hard to use efficiently what water it has and to look for other sources of water besides the SWP.

MWD is also concerned about the quality of water it receives from the SWP. Delta agricultural discharge water causes the formation of trihalomethanes (THMs), which are suspected of causing cancer. Treating this water to meet future anticipated U.S. Environmental Protection Agency (EPA) standards could cost MWD millions of dollars. MWD feels the solution to this problem lies in either controlling and treating the problems at the source, or building facilities to isolate drinking water from Delta agricultural drainage.

Water quality is one of the concerns of MWD

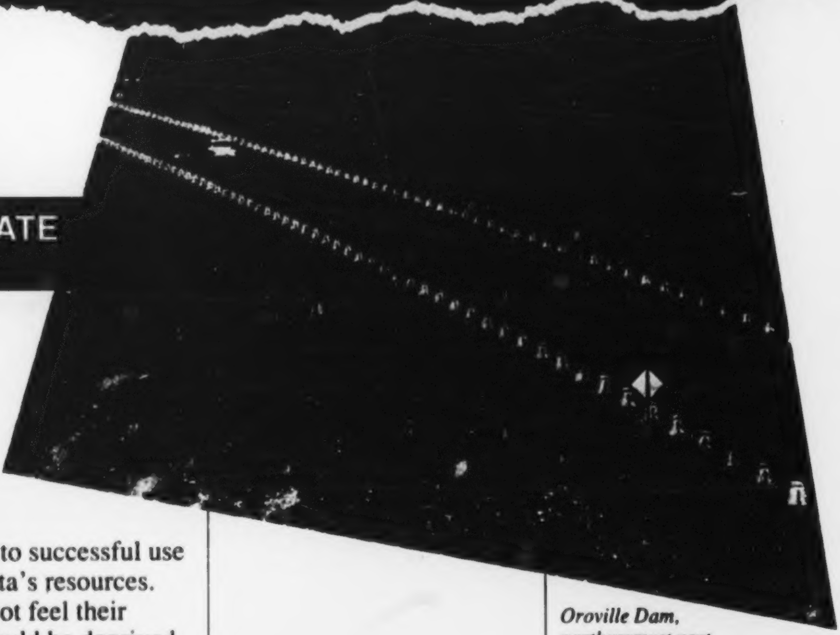
RESEARCH

Trihalomethanes

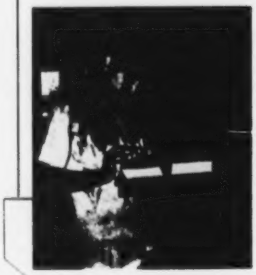
What are they? How are they formed? Why are they dangerous? How can they be removed?

GENERAL MANAGER, STATE WATER CONTRACTORS

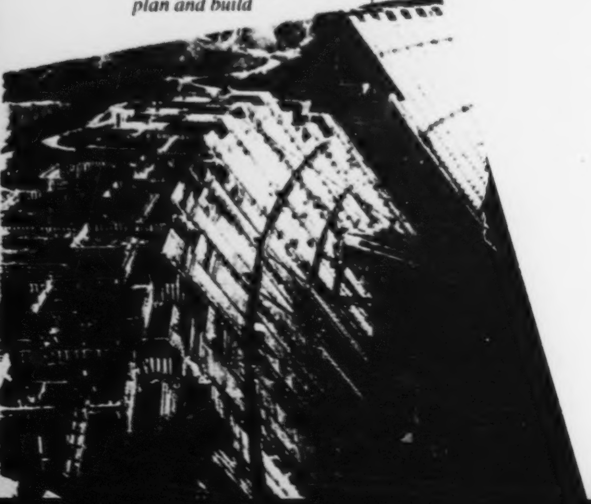
The State Water Contractors is an association representing 28 of the 30 public agencies that contract with the state for almost all of the total water supply of the State Water Project (SWP), and is responsible for repaying the project's costs. Its two largest members are the Metropolitan Water District of Southern California and the Kern County Water Agency. The group was formed to monitor the administration of the SWP and assure sufficient high quality water supply to meet its member agencies' needs. The Contractors feel that effective management is the key to successful use of the Delta's resources. They do not feel their clients should be deprived of water they currently have the legal right to use, and believe new facilities should be built to capture and store more water.


Oroville Dam, northernmost part of the State Water Project

state water contractors



Dams take many years to plan and build



RESEARCH

Dams

How long does it take to build a dam? Where are some possible sites for dams in California? Who pays for the building of a dam? Is there another way to store water in California?

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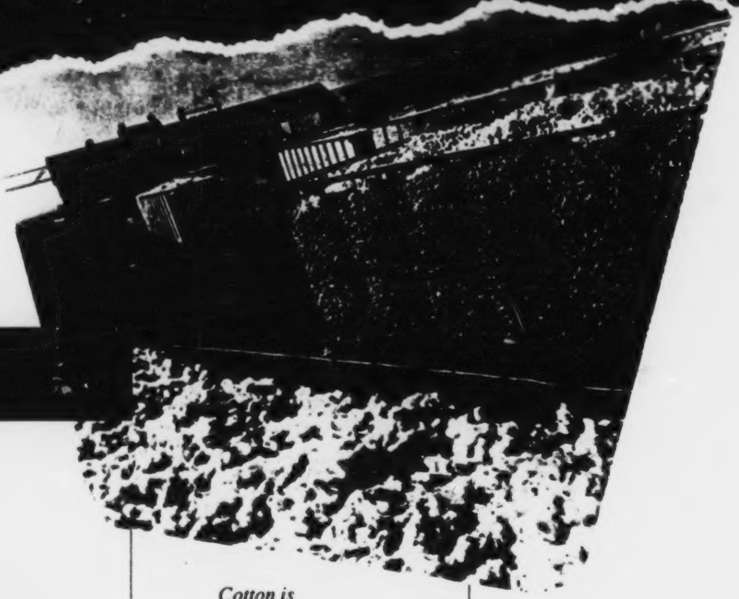


Cotton is grown in the San Joaquin Valley

MANAGER, KERN COUNTY WATER AGENCY

Kern County is a large agricultural area dependent on a constant water supply from the SWP. The Manager of the water agency fears that if the water supply from the Delta through the SWP is reduced by 60% by the year 2010, as some groups propose, the area's agricultural economy will lose close to one-half billion dollars per year and nearly 10,000 jobs. For this reason, the KCWA wants to be able to count on the same supply of SWP water, and would like to see the SWP completed. They do not want water quality standards for the Delta changed, as they fear it would lessen the amount of water available for them.

Garlic crop

RESEARCH

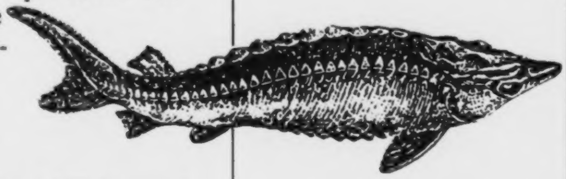
Agriculture in California

What kinds of crops are grown in the southern part of the Central Valley? How much money is earned by the sale of these crops annually? What rivers are in this region? Why don't these rivers supply enough water for irrigation?

THE DELTA DILEMMA

SENIOR RESEARCHER, THE BAY INSTITUTE OF SAN FRANCISCO

The Bay Institute is a non-profit environmental organization focusing on the needs of the Bay-Delta estuary. It sponsors, produces, and publicizes scientific, legal, engineering and economic investigations concerning the Bay's problems. The Institute also represents the Pacific Coast Federation of Fishermen's Associations. The Senior Researcher feels that the health of the Delta-Bay estuary has decreased as California's water resources have been developed. The Institute claims the wildlife of the San Francisco Bay area brings in between $932 million and $1.5 billion annually and is responsible for 73,000 to 118,000 jobs. They want spring flows of water to be high to promote phytoplankton production and to flush toxics out of the Bay.



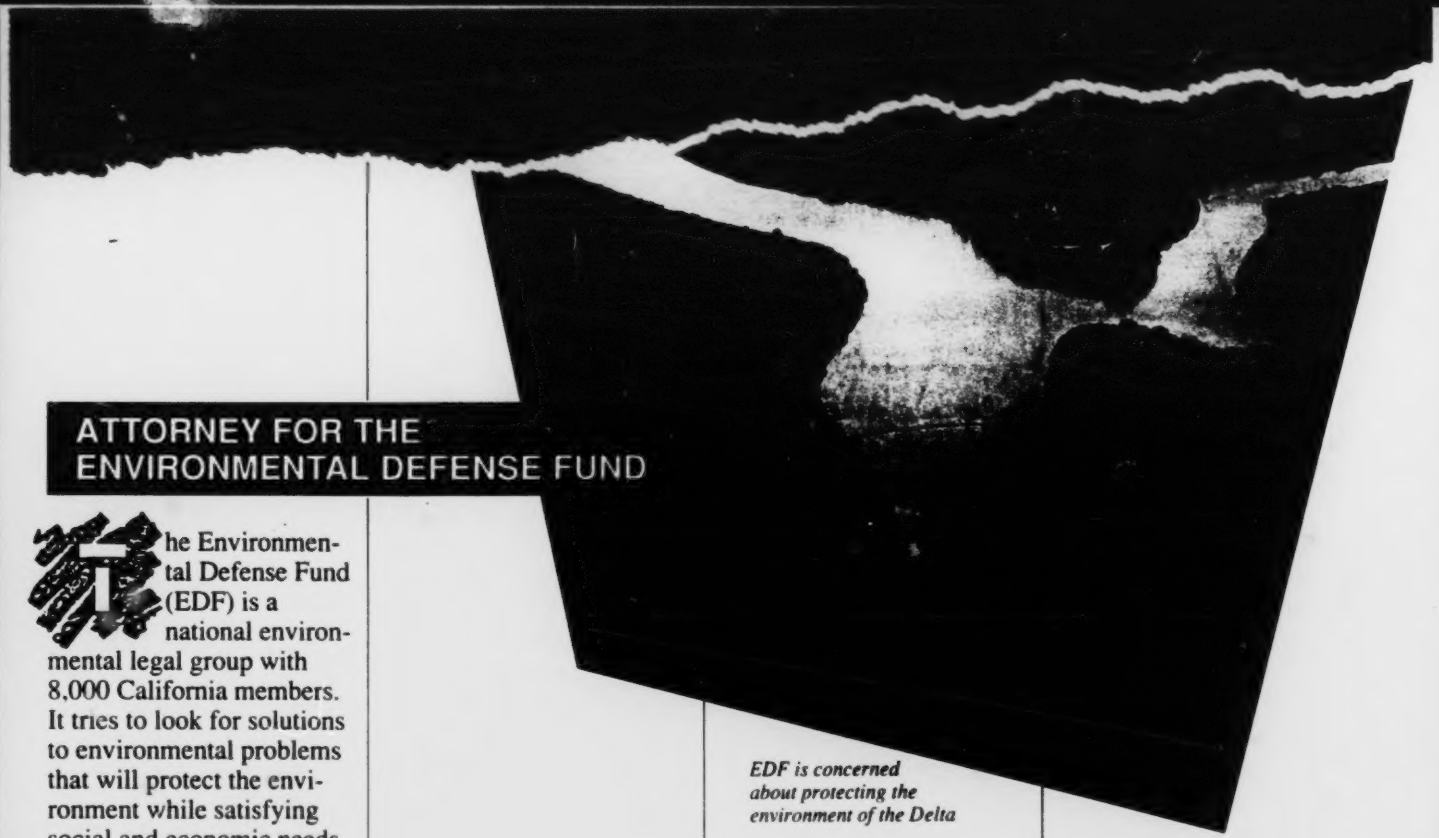
RESEARCH

What is an estuary?

Why is phytoplankton important to the rest of the wildlife in an estuary? What kinds of foods come from San Francisco Bay and the Pacific Ocean just outside the Bay?

The Bay Institute
OF SAN FRANCISCO

Aerial view of part of San Francisco Bay Estuary



EDF is concerned about protecting the environment of the Delta

ATTORNEY FOR THE ENVIRONMENTAL DEFENSE FUND

The Environmental Defense Fund (EDF) is a national environmental legal group with 8,000 California members. It tries to look for solutions to environmental problems that will protect the environment while satisfying social and economic needs. EDF also wants the water flow increased through the Delta and Bay to protect wildlife. EDF feels that water marketing would help increase the efficient use of water and thus require fewer diversions of the water flowing into the Bay.

Water marketing means the sale, transfer or leasing of water from existing uses to other uses. EDF does not want more diversions from rivers upstream until standards can be agreed upon for the amount of water that should be allowed to flow out through the Bay and maintain the health of its environment.

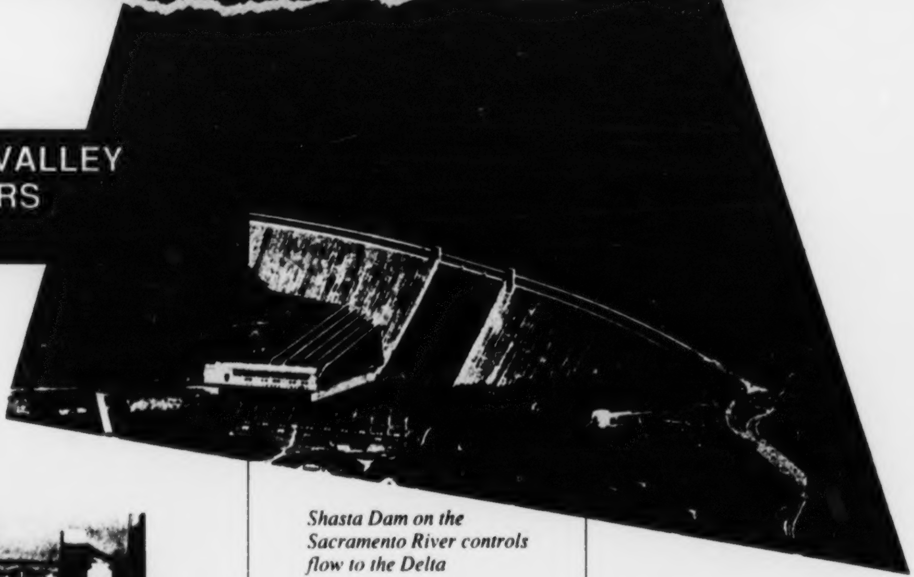
RESEARCH

Salinity

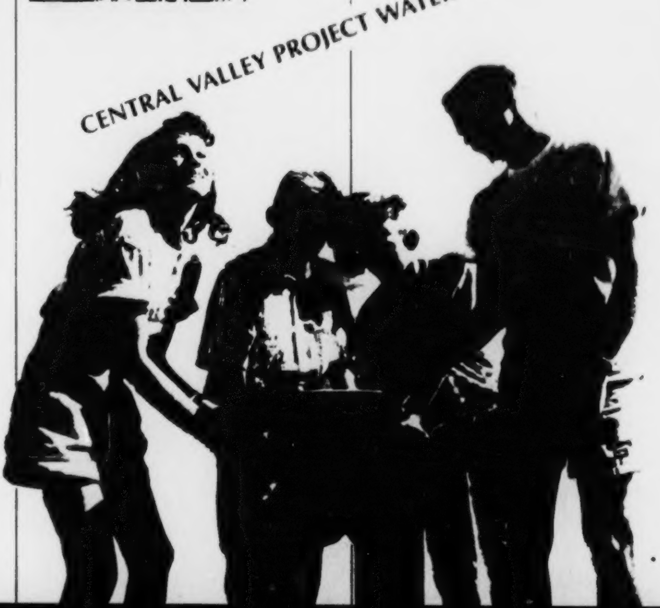
How much salt is in sea water, as compared to water in an estuary? How does salt affect different forms of wildlife? Does the area where fresh water begins to become salt water stay in one place in the Delta or does it move? How does salt affect agricultural land? How can the amount of salt water in the Delta be controlled?

DIRECTOR, CENTRAL VALLEY PROJECT WATER USERS ASSOCIATION

This group (CVPWUA) represents all water users who have long-term contracts for water from the federal CVP. Most are associated with agriculture, but some represent municipal and industrial users from north of the Delta, throughout the Central Valley, and in the East Bay area. Because the project is a federal one, the CVPWUA feels federal law may be the controlling one over regulations handed down by the California State Water Resources Control Board. They believe decisions about how much water flows out into the Bay should take into consideration the economic and social needs of the whole state, not just the area surrounding the Bay and Delta. Rather than flushing toxics out through the Bay with increased water flows, this group believes pollution problems should be dealt with at the source.



Shasta Dam on the Sacramento River controls flow to the Delta


CENTRAL VALLEY PROJECT WATER ASSOCIATION

RESEARCH

Toxics in water

Where do toxic pollutants come from? What pollutants are present in California river water? What are some methods of preventing toxics getting into our water supply?

PART II - THE KESTERSON CLEAN-UP

Ground water in the Central Valley

OBJECTIVES

Students will be able to:

1. **Explain how salts and minerals get into the water supply and how a build-up of their concentrations affects the environment.**
2. **State the relationship of ground water to surface water.**
3. **Describe how agricultural drainage water collects and harms crops, and the need for a disposal plan.**

Agricultural land on the west side of the San Joaquin Valley contains many salts, minerals, and small quantities of elements, such as selenium. "Salts" are a group of chemicals with certain characteristics. Table salt, sodium chloride, is one example. Large parts of this area also have impermeable layers of clay which stop the downward movement of water when the land is irrigated. This can result in salty ground water building up beneath the surface and eventually rising into the root zone of the crops. Two problems are therefore created for farmers. Without adequate drainage, a field can become waterlogged, like a flowerpot without a hole, stunting plant growth and reducing agricultural productivity. Also, while minerals are beneficial in small amounts, most plants can only stand limited amounts of them, so water beyond that required to meet the crop's needs is applied to saline (salty) soil to wash, or leach, excess salts from the root zone.

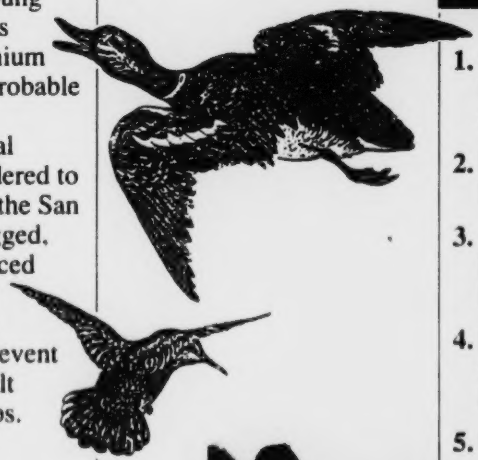
So farmers must drain water from their lands so they don't become waterlogged and also remove excess water used to leach out excess salts and minerals. They put pipes with holes in them under the surface of their lands to collect and drain away this excess agricultural water. The federal government began to build the San Luis Drain in 1968 to remove the drainage water, but some people were concerned about what would happen to the Sacramento/San Francisco Bay and Delta if the water was discharged there. As a result, the Drain was never completed and instead the water was drained into the Kesterson Reservoir, which was to be used jointly for irrigation drainage and wildlife habitat.

Continued

THE KESTERSON CLEAN-UP

As drainage water collected under ground, many minerals including an element called selenium were concentrated. Selenium is necessary for life, but only in tiny amounts. Larger concentrations of selenium are poisonous. This contaminated drainage water eventually flowed through the San Luis Drain to the Kesterson National Wildlife Refuge, where it settled in marshy ponds. In 1982, the U.S. Fish and Wildlife Service discovered unusually high concentrations of selenium in fish at Kesterson, and in 1983 and 1984 they found an alarming incidence of deformity and death among young waterfowl. Scientists concluded that selenium poisoning was the probable cause.

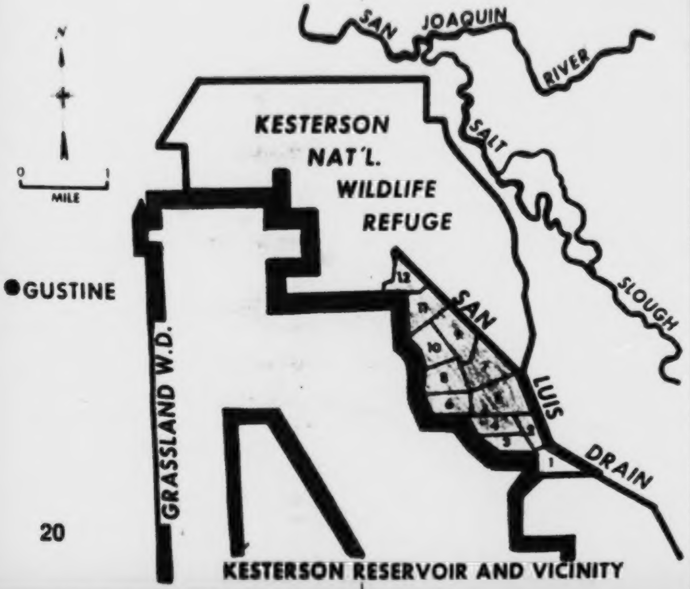
In 1985 the federal government was ordered to clean up the ponds, the San Luis Drain was plugged, and farmers were faced with the problem of dealing with excess drainage water to prevent waterlogging and salt damage to their crops.



AREA
CLOSED

THE PLAYERS

1. **Chairman of the State Water Resources Control Board**
2. **Hydrologist for the Bureau of Reclamation**
3. **Attorney for the Environmental Defense Fund**
4. **Director of the Board of Westlands Water District**
5. **Head of the Fresno County Farm Bureau**
6. **U.S. Fish and Wildlife Service biologist**
7. **Land owner/farmer of land adjacent to Kesterson**
8. **Scientist, University of California's Salinity/ Drainage Task Force**



KESTERSON RESERVOIR AND VICINITY

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THE PROBLEMS

1 A microbe has been discovered that will slowly remove selenium from the soil. Should the federal government be allowed to postpone their cleanup deadline to conduct further investigations about the possibility of using this microbe?

2 Land surrounding the Kesterson reservoir has been posted as contaminated. Should the land owner be able to collect damages from someone? Who?

3 Many people feel there are a variety of ways to deal with the Kesterson problem. The following is a partial list of solutions, which your group should prioritize (put the solution your group favors most first, then put the others in descending order of preference). You must be able to explain the advantages and disadvantages of each choice.

a. Take the farm land where the selenium-bearing soils are found out of irrigated agricultural use.

b. Complete the San Luis Drain and identify an output location, possibly in San Francisco Bay.

c. Scoop out the contaminated land at Kesterson Reservoir and bury it somewhere.

d. Pump up more ground water to dilute the salts and minerals on the farm land when it is irrigated.

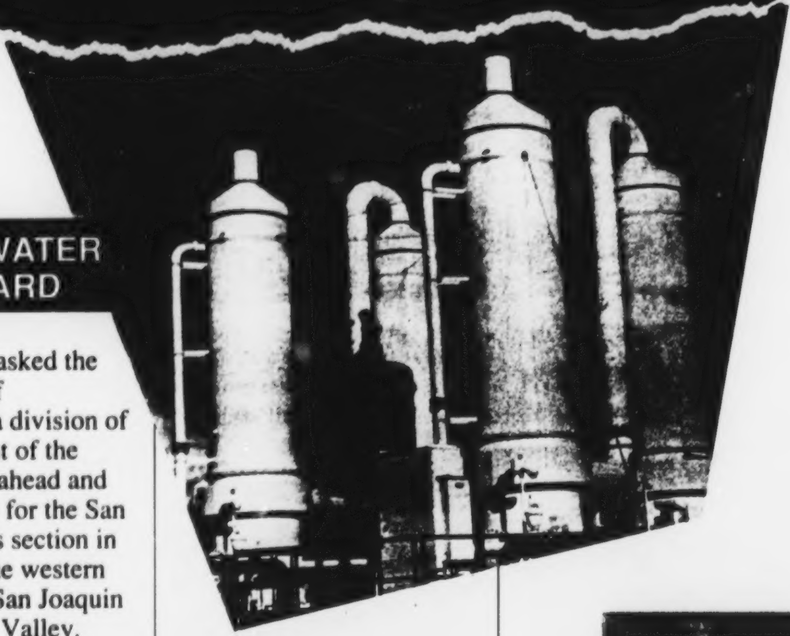
e. Drain off the contaminated water and inject it deep under the surface of the ground.

f. Only grow crops which can tolerate the high salt content.

g. Use a reverse-osmosis unit to filter out the harmful salts after the water is used for irrigation.

h. Improve farmer's efficiency in irrigating their crops so less water is used.

THE KESTERSON CLEAN-UP


Airstripping can remove toxics from ground water

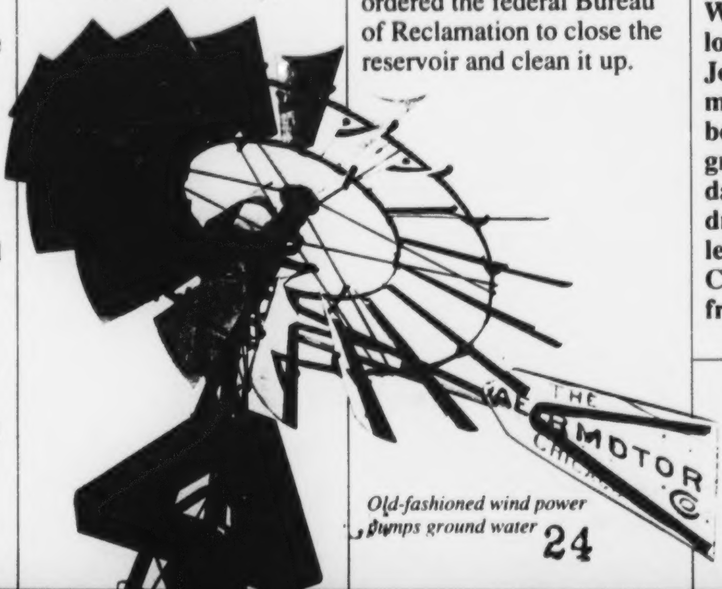
CHAIRMAN OF THE STATE WATER RESOURCES CONTROL BOARD

The State Water Resources Control Board (SWRCB) and its nine Regional Water Quality Control Boards, regulate water quality and the quantity allocated for each of the competing uses. The Board has to try to manage the state's water to best satisfy all the competing needs for water with the supply available and to protect water quality. They also have the responsibility for planning to meet future water needs throughout the state.

The water management program the SWRCB has the goal of meeting projected water demands through the year 2000. The plan stresses the importance of overall management of all water, including wastewater. It combines all of the management alternatives available, including balancing the use of surface water and ground water to reduce ground water overdraft, new water supply development, and increased conservation and reclamation.

At first, the state planned to help build the statewide drainage system, but then withdrew and asked the U.S. Bureau of Reclamation, a division of the Department of the Interior, to go ahead and build the drain for the San Luis section in the western San Joaquin Valley. When federal funding ran out because of the controversy, the SWRCB, the Department of Water Resources, and the Bureau formed an Interagency Drainage Program to study alternatives and plan for a statewide drainage system. While studies went on about the possibility of draining the water into the Bay, agricultural drainage water ran into the Kesterson area, creating a wetland wildlife habitat.

When the deformed wildlife began to show up, the SWRCB declared the drainage discharge into Kesterson, which evaporated and concentrated salts and selenium, was a "hazardous waste" because of its threat to human health and the environment. The SWRCB ordered the federal Bureau of Reclamation to close the reservoir and clean it up.



Old-fashioned wind power pumps ground water

RESEARCH

Ground Water

What is an aquifer? Where is ground water located in the San Joaquin Valley? How much ground water has been pumped out of the ground in this region to date? What is overdraft? Are toxics a problem in ground water? Can toxics be removed from ground water?

HYDROLOGIST FOR U.S. BUREAU OF RECLAMATION

The U.S. Bureau of Reclamation, a branch of the Department of the Interior, was created in 1902 under the leadership of President Theodore Roosevelt to carry out the reclamation of western lands. This included seeing that agricultural lands were provided with water so people could farm. In California, that meant the building of the dams and reservoirs of the Central Valley Project.

According to the USBR, about 2.8 million tons of salt per year come to the west side of the San Joaquin Valley with irrigation water. This salty water becomes even more salty as it is used for irrigation and must be removed to prevent crop damage. In 1960, Congress called for the construction of the San Luis Drain. By 1975, 85 miles of the drain were built and drained into the Kesterson Reservoir. The Bureau wanted to construct an extension of the drain to Suisun Bay and empty the drainage water there.

After the toxic effect of the selenium on birds was discovered, the state ordered the Bureau to close Kesterson or make it a hazardous waste impound. The Director closed the reservoir and threatened to discontinue irrigation water deliveries to the 42,000 acres from which the bulk of the drainage water originated.

The Bureau is still studying ways to clean up the site. Original estimates of the cost to scrape out the ponds and dispose of the selenium-contaminated soils ran between $37 million to $144 million.

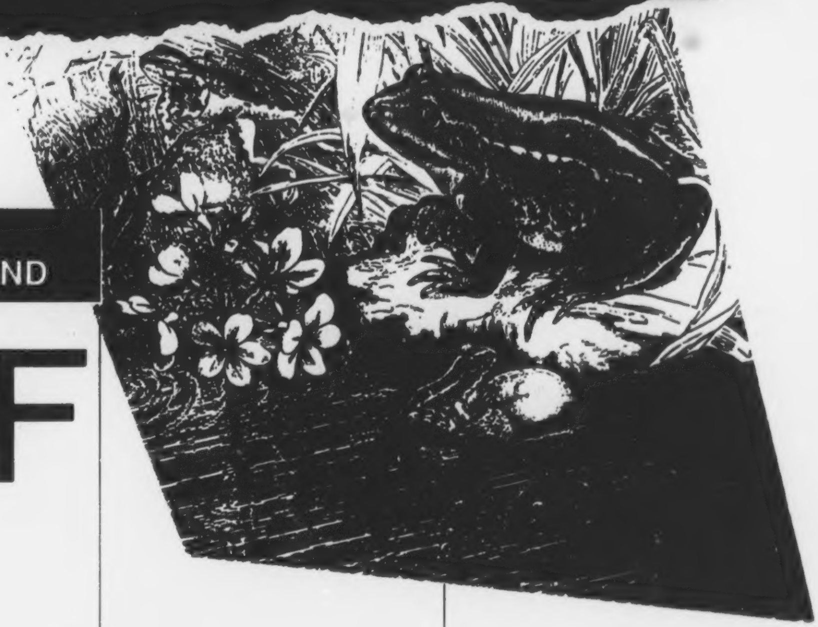
Legal hazardous waste site

RESEARCH

Hazardous wastes

What are some hazardous wastes? How do they get into the water supply? What are some ways they can be cleaned up? Are hazardous wastes harmful if they are diluted in a large body of water?

THE KESTERSON CLEAN-UP

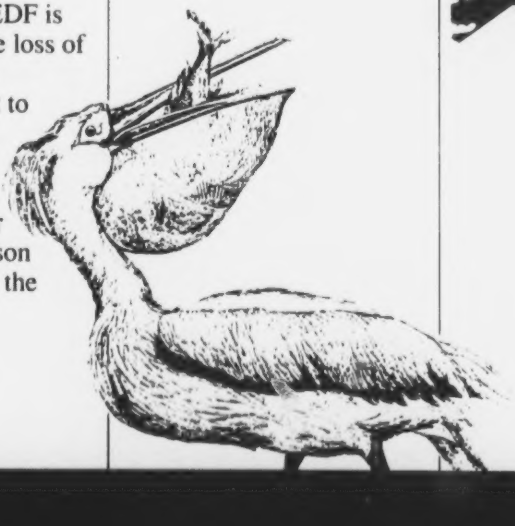


ATTORNEY FOR THE ENVIRONMENTAL DEFENSE FUND

The EDF is a national environmental legal group with 8,000 California members. The group's goal is to look for alternative solutions that protect the environment while satisfying social and economic needs. Their staff includes scientists and economists as well as attorneys.

EDF wants to see the Kesterson Reservoir cleaned up so it isn't hazardous to humans or wildlife. The group is also interested in seeing that ground and surface water is not contaminated in the future with toxic levels of selenium or other chemicals. To accomplish this, they are helping farmers seek ways to irrigate their lands which reduce the leaching rate and the volume of agricultural drainage water.

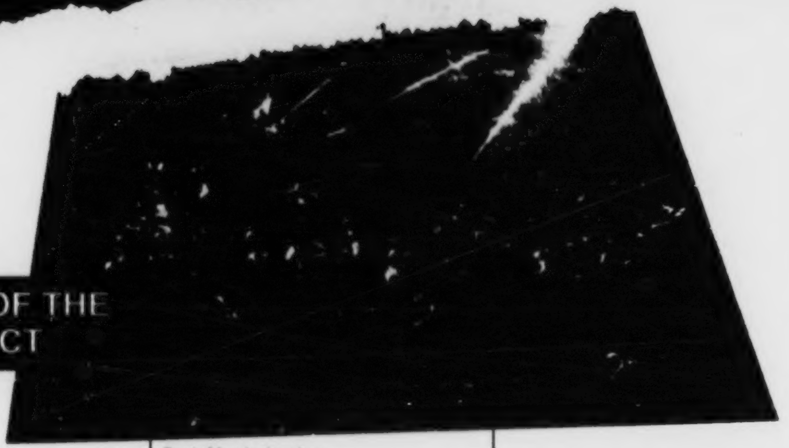
In addition, the EDF is concerned about the loss of wetland habitat for wildlife. They want to see 1,200 acres of wetlands created elsewhere in the state to make up for the fact that Kesterson has been drained in the clean up process.



RESEARCH

Wetlands

Why is this an important ecosystem? What kinds of plants and animals are found in a wetlands environment? How do wetlands affect other environments?



Sprinkler irrigation

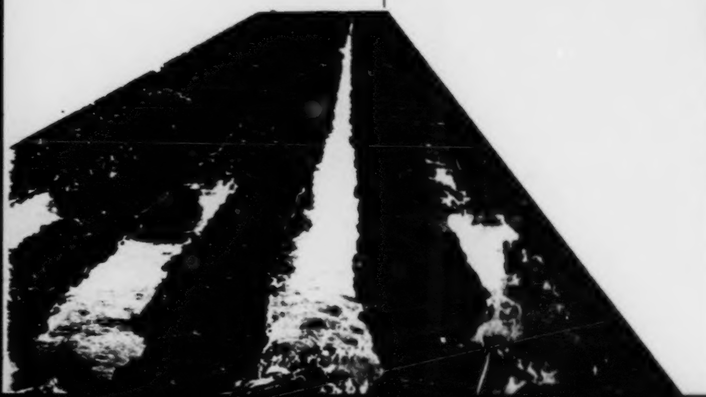
DIRECTOR OF THE BOARD OF THE WESTLANDS WATER DISTRICT

The largest single water district affected by this agricultural drainage problem is the 600,000-plus-acres Westlands Water District, which has the largest irrigated acreage in the United States. The district is located in the federal San Luis Unit Service Area on the west side of the San Joaquin Valley and is without drainage access to the San Joaquin River.

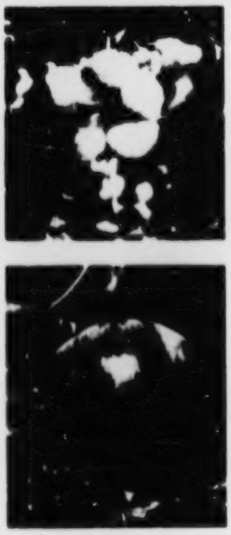
Approximately 207,000 acres of land in this district have a shallow saline water table between five and 10 feet from the surface. At depths of less than 10 feet, saline water begins to seriously affect crop productivity.

The Director was very pleased when the San Luis Drain began to be built because he felt that here was an answer to the farmers' problem of how to get rid of the drainage water coming from their fields. The San Luis System drained 42,000 acres of farmland in Westlands. But once the selenium-laced water was draining into Kesterson Reservoir and the environmental dangers of selenium were recognized, the district realized something had to be done.

In 1985 Westlands entered into an agreement with the Interior Department to phase out drainage flows by 1986 with an intensive water conservation program, diluting and recycling drainage water. They also plugged their drainage collector system. Westlands has been a leader in research into this problem.



Westlands Water District



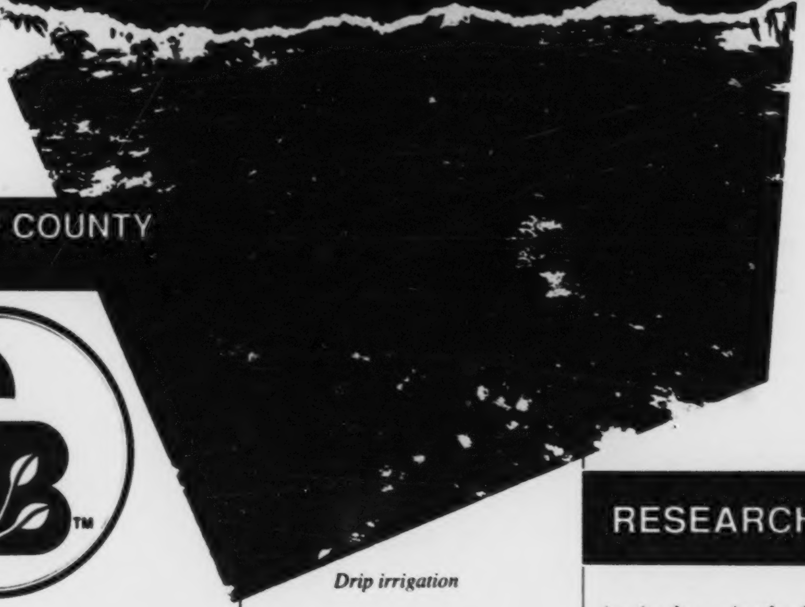
Cotton and pomegranates are grown on the west side of the valley

RESEARCH

Irrigation

How are crops watered in California? What different systems are used? What does "leaching" mean? When is this process used? How much extra water does it take for leaching? How much of California's developed water goes to agriculture?

THE KESTERSON CLEAN-UP



Drip irrigation

HEAD OF THE FRESNO COUNTY FARM BUREAU

Farming is California's number one industry. In 1987, California's farmers sold $15.6 billion worth of food and fiber. Agriculture is also a major employer, with more than 80,000 families and as many as 400,000 workers growing and harvesting crops. According to the California Farm Bureau Federation, one out of every three people employed in California works at an agriculture-related job.

When a farmer's soil is salty, as it is in Fresno County, in the western San Joaquin Valley, farmers have to think carefully about their irrigation practices. If the soil retains too much water, not allowing sufficient air to reach the roots of the crop, artificial methods for draining the excess water from the root zone often are employed. Farmers bury pipes with holes in them below the ground's surface to carry off excess water. If the soil is salty, the farmer usually must apply about 10 to 25 percent more water than the crop needs in order to get uniform irrigation coverage over the entire field and at the same time leach salts from the root zone - sometimes leading to charges that the farmer is wasting water.

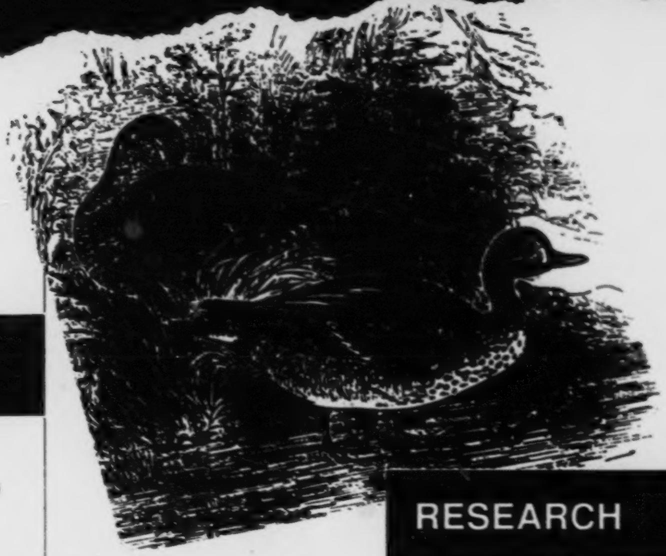
When the water table is shallower than 10 feet, crop productivity can be severely affected. This area had crop production losses of nearly $150 to $415 per acre, or approximately $35 million in 1987.

The Farm Bureau is concerned that much of the land in the area supplied by the Westlands Water District will have to be taken out of production unless the drainage problem can be solved. Because this is such productive land, the Farm Bureau wants to help farmers learn alternative methods of irrigating that use less water and decrease the amount of agricultural drainage that has to be managed.

RESEARCH

Agriculture in the San Joaquin Valley

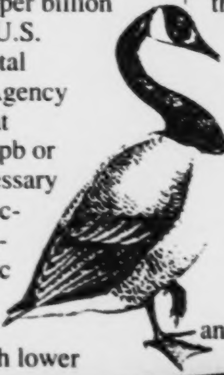
What crops are produced there? How much money is earned from the sale of these crops? Do these crops require a lot of water? Are there other crops that could be grown here? Would drip irrigation be effective and affordable?



U.S. FISH AND WILDLIFE SERVICE BIOLOGIST

In 1982, the U.S. Fish and Wildlife Service (FSW) discovered unusually high concentrations of selenium in fish at Kesterson Reservoir and in 1983 and 1984 turned up an alarming incidence of deformity and death among young waterfowl at Kesterson. Scientists concluded that selenium poisoning was the probable cause.

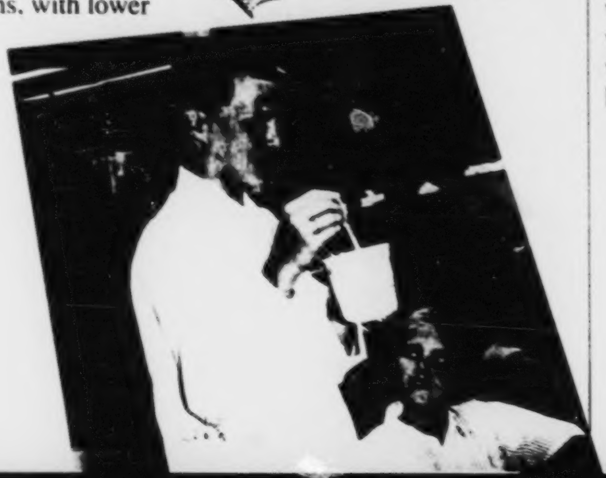
Testing of the drainage water flowing into the reservoir revealed that selenium levels ranged from 85 to 440 parts per billion (ppb). The U.S. Environmental Protection Agency indicates that levels of 5 ppb or less are necessary for the protection of freshwater aquatic organisms in flowing streams, with lower levels necessary when aquatic life is exposed to standing water, such as that in a marsh or pond.



Although selenium in trace amounts is essential to all animal life, it has long been known to be harmful and even lethal in high concentrations. Fish and wildlife may become exposed to harmful concentrations of the element when it accumulates in the body tissues of a plant or animal and then that organism is eaten by another organism. When many of these organisms are eaten by a species higher in the food chain, their stores of selenium are passed on. This process is known as bioconcentration. Eventually selenium can attain levels in the tissues and organs of complex organisms which limit reproduction and cause deformities and possibly death among waterfowl, other birdlife and fish.

To reduce the number of birds exposed to the contamination at Kesterson, the FSW began a hazing program which involved firing blanks from guns to make noise and scare birds from landing at the reservoir.

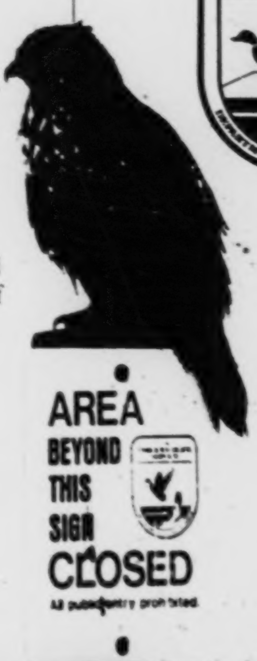
The FWS would like to see agricultural drainage from selenium-bearing soils halted because of the harmful effects of bioaccumulation and the Kesterson Reservoir cleaned up. Because wetlands are an important area for wildlife, especially migratory birds, the FWS would like to see land elsewhere dedicated to wetlands and provided with a secure supply of healthy water.



RESEARCH

Migratory birds

Where do they come from and go to? What kinds of birds need marshy areas? What do these birds eat? What kinds of nests do they make? What would happen if all the marshy areas or wetlands in California were eliminated?



THE KESTERSON CLEAN-UP

LAND OWNER-FARMER, ADJACENT TO KESTERSON RESERVOIR

On March 15, 1985, Secretary of the Interior Donald Hodel ordered immediate steps to begin closure of Kesterson Reservoir and threatened to discontinue irrigation water deliveries to 42,000 acres of Fresno County land supplied by Westlands which was draining into Kesterson. He stated that continuing to operate the reservoir could cause Department of Interior employees to be in violation of the Migratory Bird Treaty Act, a criminal statute. Landowners and merchants feared that tens of thousands of acres of farmland might be put out of production.

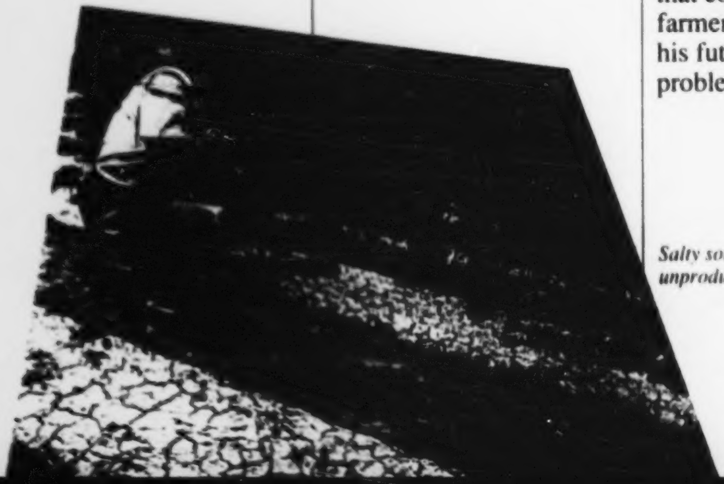
The farmer, whose drainage water empties into the San Luis Drain, was allowed to continue to get water for his crops because the Department of the Interior agreed to a gradual phase-out of drainage flows. He is still able to get water, but his land is becoming waterlogged because the drain was plugged. The Westlands Water District helped him design a plan to recycle his drainage water, reusing it for irrigation after diluting it with fresh water. But he is concerned that no permanent solution has been found.

One option explored by Westlands and other districts, is deep well injection. This injection of waste water into the earth is promising for disposal, but this does not solve the treatment problem. It just disposes of salty, but potentially valuable water that could be reused. So this farmer is concerned about his future if the drainage problem is not solved.

RESEARCH

Salt tolerance

What are some crops that can stand increased amounts of salts? Can a farmer make as much money growing these kinds of crops as ones that are sensitive to salt?



Salty soil is unproductive soil

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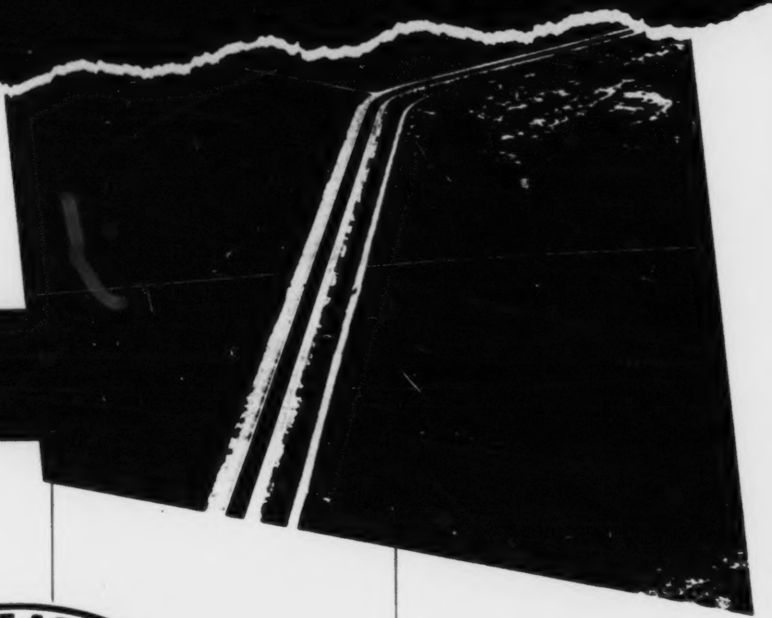


Aerial view of Kesterson Reservoir and San Joaquin Drain

SCIENTIST, UNIVERSITY OF CALIFORNIA'S SALINITY/ DRAINAGE TASK FORCE

The University of California's Salinity/Drainage Task Force was established to develop, interpret, and disseminate research knowledge addressing salinity, drainage, selenium and the toxic element problems in the San Joaquin Valley.

Scientists are finding ways to accelerate the volatilization of selenium by adding amendments such as orange peels or cottonseed meal to soil. Chemical reactions between the amendment and selenium cause the rate at which selenium transforms from a solid to a gas to increase. Eventually soil scientists hope to discover a means to vent selenium to the atmosphere at a rate fast enough to make possible the restoration of Kesterson Reservoir. Other scientists worry that ground water may continue to supply the surface soils with selenium, frustrating the effectiveness of the volatilization process.

THE COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

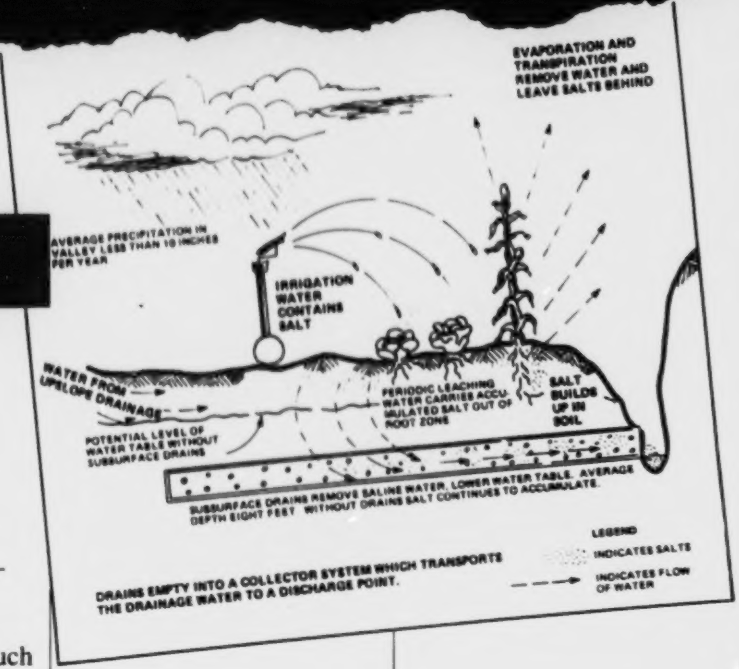
UC DAVIS

RESEARCH

Selenium

What is selenium? Where does it come from? How does it get into soils? How does it hurt birds? At what concentration is selenium hazardous to humans and wildlife?

THE KESTERSON CLEAN-UP


EVAPORATION AND TRANSPIRATION REMOVE WATER AND LEAVE SALTS BEHIND
AVERAGE PRECIPITATION IN VALLEY LESS THAN 10 INCHES PER YEAR
IRRIGATION WATER CONTAINS SALT
WATER FROM UPSLOPE DRAINAGE
PERIODIC LEACHING WATER CARRIES ACCUMULATED SALT OUT OF ROOT ZONE
SALT BUILDS UP IN SOIL
POTENTIAL LEVEL OF WATER TABLE WITHOUT SUBSURFACE DRAINS
SUBSURFACE DRAINS REMOVE SALINE WATER, LOWER WATER TABLE. AVERAGE DEPTH EIGHT FEET WITHOUT DRAINS SALT CONTINUES TO ACCUMULATE.
DRAINS EMPTY INTO A COLLECTOR SYSTEM WHICH TRANSPORTS THE DRAINAGE WATER TO A DISCHARGE POINT.
LEGEND
INDICATES SALTS
INDICATES FLOW OF WATER

GEOLOGIST, U.S. GEOLOGICAL SURVEY

Scientist, U.S. Geological Survey, assigned to the San Joaquin Valley Drainage Program. The San Joaquin Valley Drainage Program was created in mid-1984 to study the drainage problem, the toxic effects of selenium, and to propose some solutions. The U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Geological Survey, California Department of Fish and Game, and California Department of Water Resources are all participating agencies.

The Drainage Program scientists have determined that the area affected by shallow groundwater will continue to increase if the current practice of applying as much as one acre-foot per acre per year of water in excess of plant needs is not changed. Intensive water management to reduce the volume of subsurface drainage is needed. Alternatively, such lands may be retired from irrigation.

The Drainage Program has devised a multiple water-use plan to maximize the beneficial use of irrigation water and minimize the cost and harmful effects of managing drainage water. Water from a supply canal is applied to salt-sensitive crops, just like today's irrigation. However, under the multiple-use plan, the drainage water from the salt-sensitive crops is collected and used to irrigate more salt-tolerant crops, such as cotton and barley. Drainage water from the salt-tolerant crops is then collected and used for a third time to irrigate a tree crop such as eucalyptus, which can eventually be harvested and used or sold for fuel. Drainage water from the tree crop would be sent to an evaporation pond. The sludge left over after evaporation would have to be disposed of in a safe way.

RESEARCH

Salts in soil

What are salts? How do they get into soils? Why do salts build up in irrigated areas with poor drainage? How do salts harm crops? Are evaporation ponds harmful to the environment? How can the sludge be disposed of?

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PART III - COLORADO CUT-BACK

OBJECTIVES

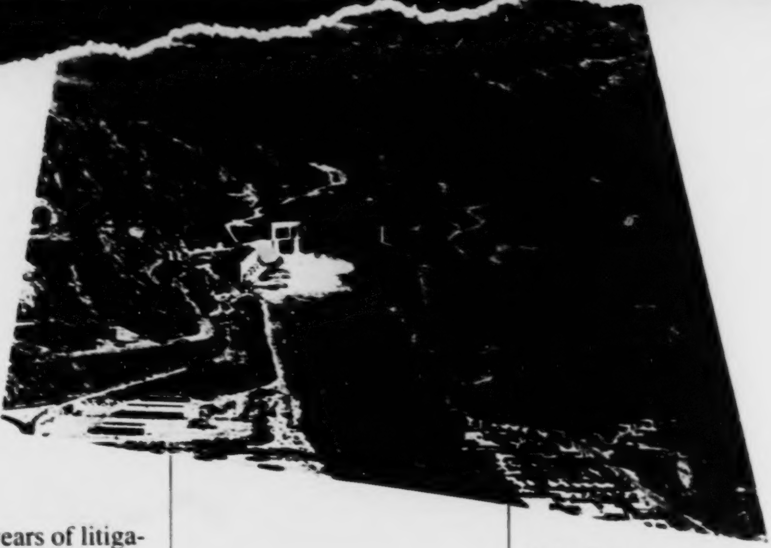
Students will be able to:

1. **Explain the different sources of water for Southern California.**
2. **Suggest alternatives for obtaining water for Southern California's growing population.**
3. **Describe agricultural and urban water conservation techniques.**

The turbulent Colorado River is one of the most controversial and heavily regulated rivers in the world. The waters of the 1,440 mile-long river are shared by seven states, several Indian tribes and the Republic of Mexico. The Colorado supplies water to 17 million people and more than one million acres of once-desert farmland. Most of Southern California's electricity is a product of the Colorado River.

After 11 years of litigation, in 1964 the U.S. Supreme Court made a ruling on how the Colorado's lower waters should be divided up between California and Arizona. Now the Central Arizona Project has been completed and California's water contracts of 5.3 million acre-feet per year have been cut back to 4.4 million, with the Metropolitan Water District of Southern California losing half of its current entitlement of more than 1.2 million acre-feet. MWD includes the urban south coast from Santa Barbara to San Diego.

The loss of close to a million acre-feet of water a year has caused southern California to look to northern California for more water, to be transported down through the California Aqueduct. It has also caused southern California to consider some innovative water management techniques and to stress conservation to farmers and city-dwellers alike.



Parker Dam on the Colorado River

THE PLAYERS

1. **Director, California Department of Water Resources**
2. **Secretary, U.S. Department of the Interior**
3. **General Manager, Imperial Irrigation District**
4. **General Manager, Metropolitan Water District of Southern California**
5. **Farmer, in southwestern Arizona**
6. **Governmental water agent, Republic of Mexico**
7. **Director, Los Angeles Department of Water and Power**
8. **Attorney, Environmental Defense Fund**

THE COLORADO RIVER CUT-BACK

THE PROBLEMS

1 The Colorado River is a very salty river. This is because the force of the water against the steep gradient and the composition of the rock formations in the Colorado basin contribute to the river's excessive amount of erosion. The river carries more silt than most rivers, and has a high concentration of dissolved minerals in the water. The farther the Colorado flows, the saltier it becomes.

In 1922, a national commission divided up the waters of the Colorado River between the upper and lower basins. Using records of the previous 30 years (which had actually been unusually wet ones), the commission believed that there would be plenty of water left in the river for Mexican users. In 1944 the United States signed a treaty with Mexico guaranteeing them 1.5 million acre-feet a year in Colorado River flow.

During the years when Lake Powell was filling behind Hoover Dam, very little water went beyond the dam. Most of the water flowing into the river was very saline agricultural drainage water from the Wellton-Mohawk Project near Yuma, Arizona. The quality of the water in the lower river was so salty that it was unusable even for irrigation purposes for the Mexican farmers, and was the cause of an international disagreement between Mexico and the U.S. In 1973, the two countries reached an agreement that said the water delivered to Mexico from Morelos Dam would contain no more than 115 milligrams per liter total dissolved salts.

The U.S. is building an expensive desalinization plant to meet salinity requirements agreed upon with Mexico. The plant is to be completed in the early 1990's and will be very expensive to operate. Should this plant be completed or should some farmland be purchased and retired from use to save water and thus reduce the salinity level?

2 Where should the water for southern California come from to replace what they are losing when Arizona starts taking its full entitlement? The following are some proposed alternatives. Your group should prioritize them, with your favorite alternatives listed first, and least favorite last. Be able to explain the advantages and disadvantages of each alternative.

a. Import more water from northern California via the California Aqueduct.

b. Increase urban and agricultural water conservation.

c. Import more water from the eastern side of the Sierra.

d. Line all canals and aqueducts bringing water into southern California with cement to prevent water seeping into the soil and being lost.

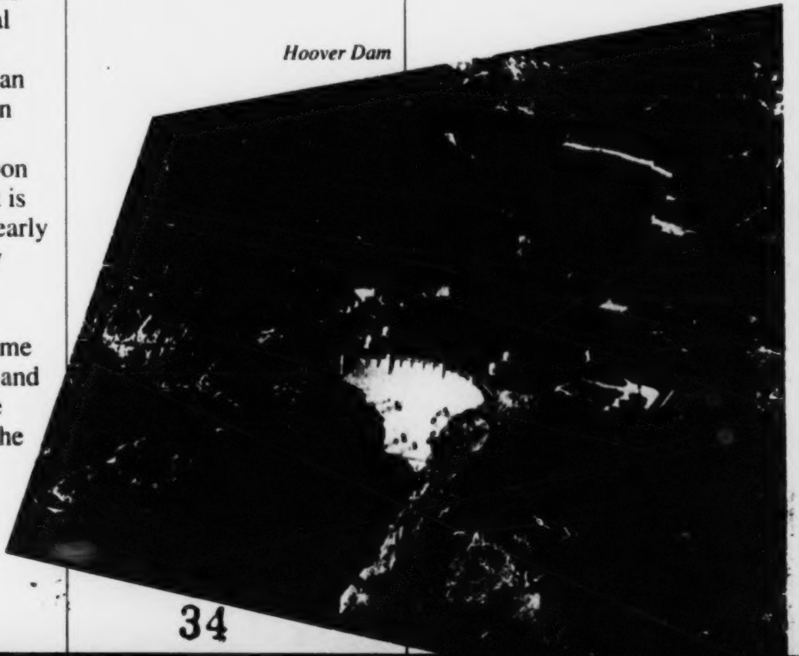
e. Arrange for water transfers between agricultural communities with excess water and major urban areas.

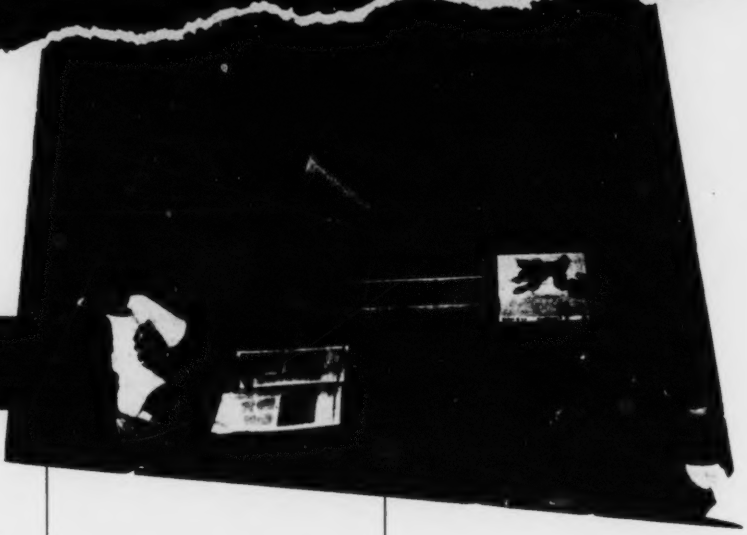
f. Pay farmers to take land out of production and use the water from their entitlements for urban use.

g. Increase pumping of ground water to meet urban and agricultural needs.

h. Build more dams to store water in reservoirs.

Hoover Dam





DIRECTOR, CALIFORNIA DEPARTMENT OF WATER RESOURCES

The California Department of Water Resources (DWR) serves two principal functions: statewide water planning, and developing and managing the State Water Project (SWP). DWR feels that reduction of southern California's Colorado River water supply will create increased demands on the SWP, and will mean the moving of more water south from northern California.

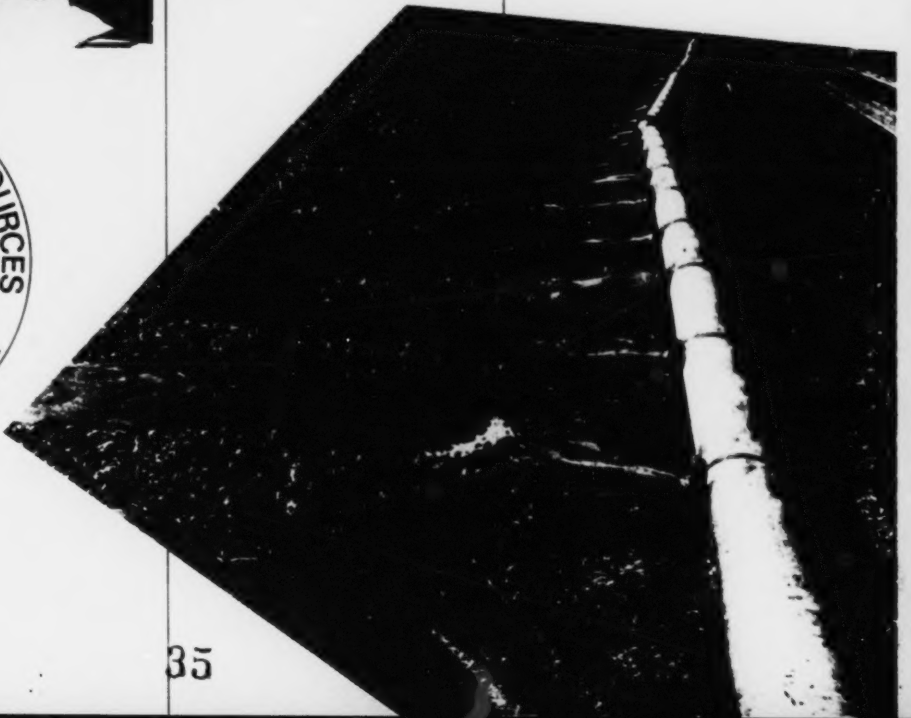
DWR investigated the claim of a farmer who lived next to the Salton Sea, and found that the Imperial Irrigation District was wasting water, about 438,000 acre-feet annually. DWR made a report to the State Water Resources Control Board which then ordered IID to come up with a water conservation program which would reduce the inflow to the Salton Sea by 100,000 acre-feet per year.

State law directs the DWR to encourage water transfers between agencies and to offer technical help to districts like IID and MWD who are considering trading water for resources necessary to accomplish a conservation program.

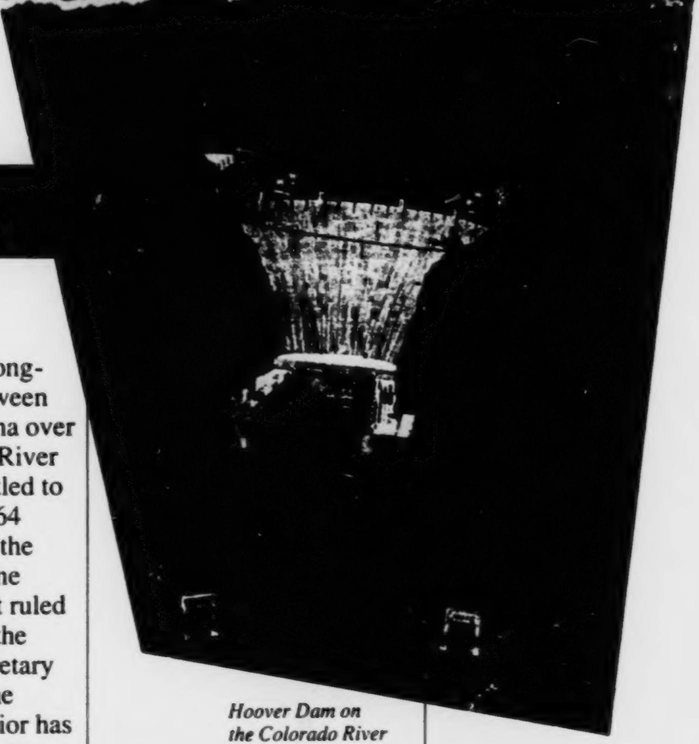
RESEARCH

Salts in water

How do salts (dissolved minerals) get into rivers? How much salt is in the Colorado River? How does this compare to other California rivers? Why is this salt a problem for farmers who use this water for irrigation?



THE COLORADO RIVER CUT-BACK



Hoover Dam on the Colorado River

SECRETARY, U.S. DEPARTMENT OF THE INTERIOR

All the dams on the Colorado River are operated by the Bureau of Reclamation, an agency of the U.S. Department of the Interior. The Secretary of the Interior makes the decisions which control distribution of the water from these projects. The Interior Secretary's decisions are to be in accordance with all the documents that make up "The Law of the River." "The Law of the River" is made up of interstate agreements, contracts, an international treaty, state and federal legislation, a Supreme Court decision and federal administrative actions.

MARCH 3, 1849

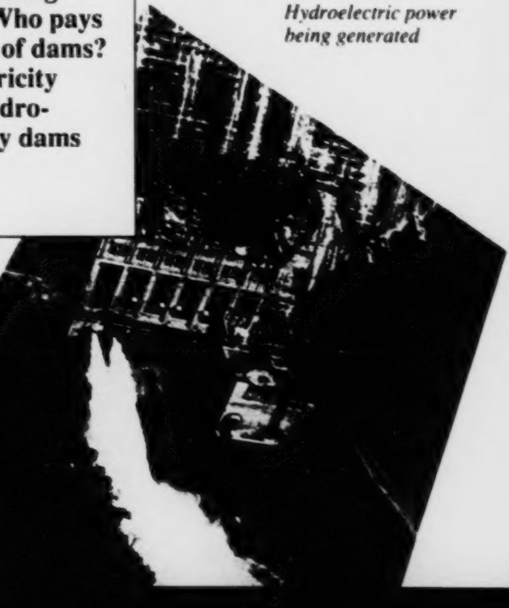
The main dams and reservoirs that affect southern California are Hoover Dam and its Lake Mead, Davis Dam and its Lake Mojave, Parker Dam and its Lake Havasu, and Imperial Dam. The All-American Canal began delivering water from the Imperial Dam to the Imperial Valley in 1942.

There has been a long-standing conflict between California and Arizona over how much Colorado River water each was entitled to use. In a 1964 decision the Supreme Court ruled that the Secretary of the Interior has the power to determine how the Colorado River water would be apportioned among the states bordering it. Even though Arizona had not participated in earlier agreements dividing the river's waters, this decision meant Arizona would receive its entitlement, which meant California's entitlement would be cut back.

RESEARCH

Hoover Dam

When was it built? How large is it? How much water is stored behind it? Why was its building controversial? Who pays for the building of dams? How is the electricity generated by hydro-electric plants by dams sold?



Hydroelectric power being generated

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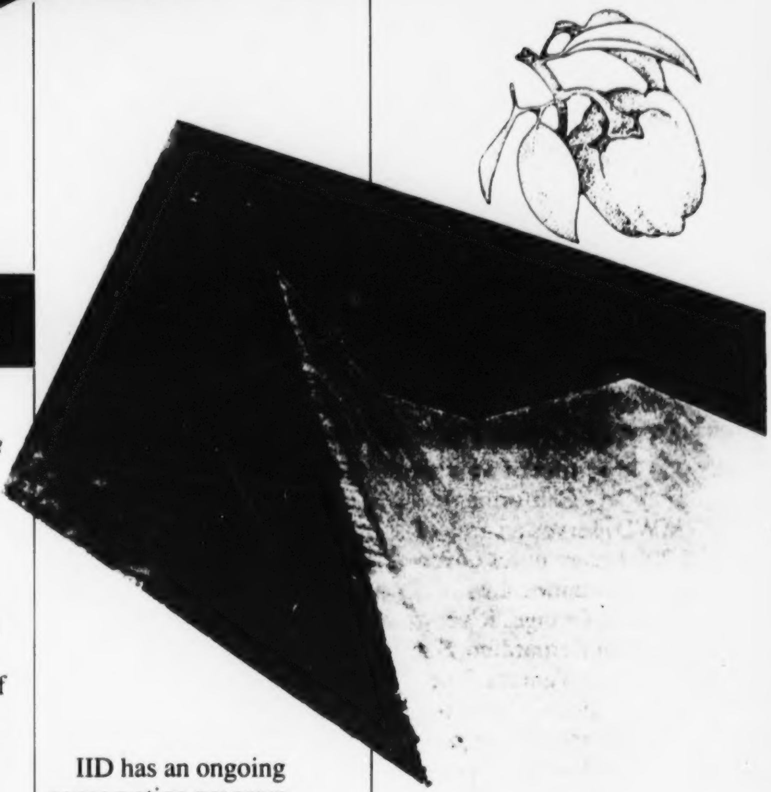


Canal lining project

GENERAL MANAGER, IMPERIAL IRRIGATION DISTRICT

The Imperial Irrigation District (IID) encompasses over one million acres, nearly half of which is under irrigation. The valley's warm temperatures and mineral-rich soils make it an agricultural wonderland, producing over $700 million annually, making it the world's sixth largest agricultural producing area. Agriculture uses 98% of the valley's water which comes from the Colorado River, diverted by the Imperial Dam, carried over 80 miles through the All-American Canal.

The Colorado River is extremely salty, carrying ten million tons of salt annually downstream. In the agriculturally rich Imperial Valley, one ton of salt accumulates each year per acre-foot of Colorado River water used. Salt damage could double by the year 2020, with an annual loss to California farmers of more than $75 million.

To deal with the highly saline Colorado River water, farmers periodically leach their fields, or apply more water than is needed by crops, to wash salts (dissolved minerals) out of the root zone. As early as the 1920s, accumulating salts and a rising water table threatened productivity and drove some lands out of production. In 1929, underground tile drainage systems were introduced to carry salty drainage waters into the now more than 1,457 miles of surface drains and on into the Salton Sea. Since the tiling program began, more than 31,551 miles of tile have been laid in 90 percent of the valley farms.

The Imperial and Coachella Valleys and Mexico produce agricultural drainage water that goes into the Salton Sea. The rising level of the Salton Sea threatens agricultural land around its edges and law suits have resulted.

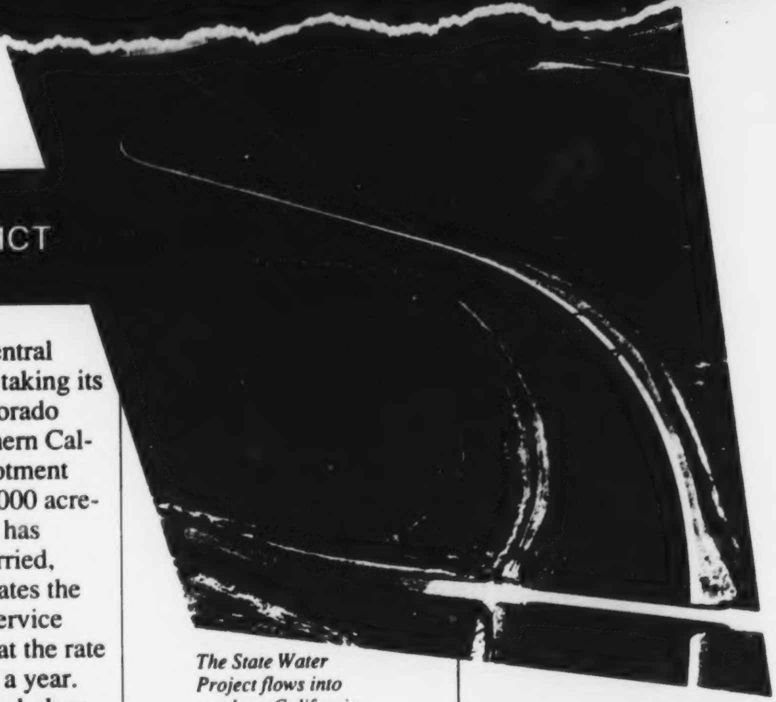
IID has an ongoing conservation program which includes lining canals to prevent water seepage (a very expensive process), pumpback systems to reuse agricultural drainage water, and stiff penalties for water wasters. IID will be selling the water it is conserving to the Metropolitan Water District of Southern California (MWD). MWD will pay for the lining of IID's canals, in exchange for which, IID will give MWD the amount of water saved, water which would otherwise sink into the ground.

RESEARCH

Agriculture in the Imperial valley

What crops are grown there? How much money do they bring in annually? Could crops requiring less water be grown here? Can a farmer earn as much from crops requiring less water? Can more salt tolerant crops be grown here? Can a farmer earn as much from salt tolerant crops?

THE COLORADO RIVER CUT-BACK



The State Water Project flows into southern California

GENERAL MANAGER, METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

The Metropolitan Water District of Southern California (MWD) serves an area of 5,200 square miles covering six counties: Los Angeles, Orange, Riverside, San Bernardino, San Diego and Ventura. The $220 million Colorado River Aqueduct was completed in 1941 and with recent expansions has been delivering more than 1.2 million acre-feet a year to southern California, carrying water 242 miles from the Colorado River.

MWD also buys water from the State Water Project. This water is transported south from the Sacramento-San Joaquin Delta through the 444-mile-long California Aqueduct. MWD has contracted with the state for delivery of more than 2 million acre-feet a year (1.8 billion gallons a day).

Now that the Central Arizona Project is taking its entitlement of Colorado River water, Southern California's water allotment will be cut to 550,000 acre-feet per year. This has water officials worried, since MWD estimates the population of its service area is expanding at the rate of 180,000 people a year.

MWD has several plans to provide water for its growing population, especially in times of water shortage. MWD is offering money to farmers in the Palo Verde Valley for taking their land out of production, thus saving water for urban needs. MWD also has agreed to pay for concrete lining for some of the canals belonging to the Coachella Valley Water District in exchange for the water now lost to percolation into the ground. And it has established underground water banks in Chino, Coachella Valley and Kern County to "bank" water in wet years for use during dry years. They plan to inject water into underground aquifers during wet years and then be able to pump it out from wells during dry years.

MWD has also agreed to finance a water conservation program for the Imperial Irrigation District. Studies by governmental agencies and engineering companies indicate as much as 300,000 to 400,000 acre-feet of water per year could be conserved by the IID and used elsewhere without significantly harming farming within the area. Most of this excess irrigation water now flows into the Salton Sea or is lost by seepage from irrigation canals.

RESEARCH

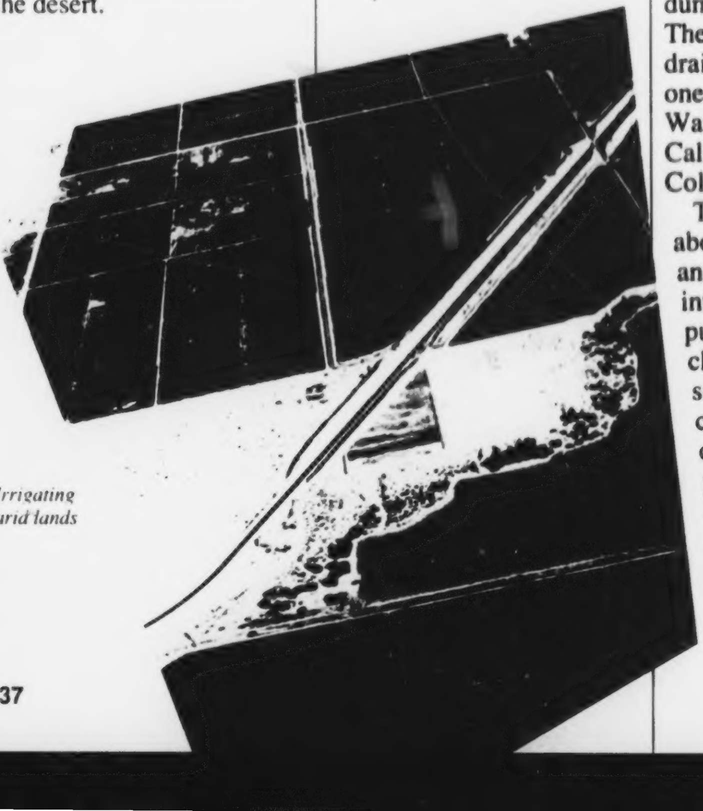
Ground water and reclamation

What is an aquifer? How is it formed? How does water get into an aquifer? What happens when water is pumped out? Can water be pumped back in? How can water be reclaimed? How can waste water be treated so it can be used again? What is a saline sink?

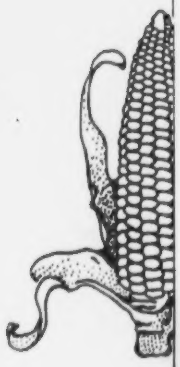
FARMER, IN SOUTHWESTERN ARIZONA

When the seven states that share the Colorado River's waters met in 1922 to reach an agreement on how the waters were to be divided up, part of the plan was that Arizona would develop its own water. The Central Arizona Project (CAP) originally was supposed to supply farmers in Arizona with water for their crops, but eventually the CAP included growing urban areas in its plan. Eventually about 1.2 million acre-feet of water will be carried hundreds of miles across the desert.

Arizona is currently pumping out 2 million acre-feet of ground water more than nature puts back each year. Some people feared that more water in Arizona would mean that agriculture will expand and require more water, although laws have been passed to control this. About 60 percent of the agricultural supply came from the ground before the CAP, and it was even saltier than the Colorado River water.



Irrigating arid lands



This farmer lives and works in the Wellton-Mohawk area. This was the area where the salty agricultural drainage water was causing a problem for Mexico when it was put back into the Colorado River. As a result, the Welton-Mohawk project had to drain its water by a separate canal directly into the Gulf of California. Unfortunately, this means hundreds of thousands of acre-feet of salty, but valuable water are being dumped instead of reused. The average amount of drainage is equal to about one fourth of Metropolitan Water District of southern California's annual Colorado River allotment.

This farmer is concerned about economic groups and environmental interests which are pushing for governmental changes in federal water supply contracts. This could force him to change his farming practices, or even take his land out of production.

RESEARCH

Agriculture in Arizona

What crops are grown there? How much land is under cultivation? How important is agriculture to the economy of Arizona?

THE COLORADO RIVER CUT-BACK

GOVERNMENTAL WATER AGENT, REPUBLIC OF MEXICO

The Colorado River carries ten million tons of salt annually. The river flowing into the Imperial Dam contains about 2,000 pounds of salts per acre-foot. Salinity increases downstream as water is lost through evaporation and removed for irrigation. Minerals increase in concentration because they are carried in less water. Extreme salinity can damage soil and crops and can corrode pumps, household plumbing and machinery. Highly-saline water is not suitable for municipal water supply or industrial and agricultural uses without treatment to remove minerals.

California's first irrigation of the Imperial Valley was by a canal, an old overflow channel of the river that went through Mexico. Mexico allowed American settlers to use the diversion in exchange for half the water. A flood in 1905 and the Mexican Revolution in 1910 convinced Americans that they wanted their own canal with no influence from Mexico, so they built the All-American Canal. In 1944, the United States agreed to deliver 1.5 million acre-feet of Colorado River water to Mexico annually. This agreement is one of the documents that makes up "The Law of the River."

As water is used for irrigation along the Colorado River and agricultural drainage is returned to the river, it becomes saltier. Gradually, the water left in the Colorado River for Mexican use became saltier and saltier. Eventually the water reaching Mexico was unsuitable for irrigation.

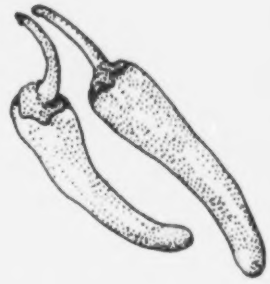
In 1973, the United States made an agreement with Mexico to improve the quality of water that was delivered to Mexico. To meet this agreement, a large desalination plant near Yuma, Arizona, will be built at a cost currently expected to be $470 million. This Bureau of Reclamation plant will produce 73 million gallons a day of reclaimed irrigation water. With most of the salt removed, the water will be blended back to the Colorado flowing to Mexico at a salinity level low enough for Mexican farmers to use again. None of the water will be used in the United States but will fulfill our treaty obligation with Mexico. Critics say retiring nearby land from irrigation by buying out some local farmers would be cheaper than constructing the desalination plant.

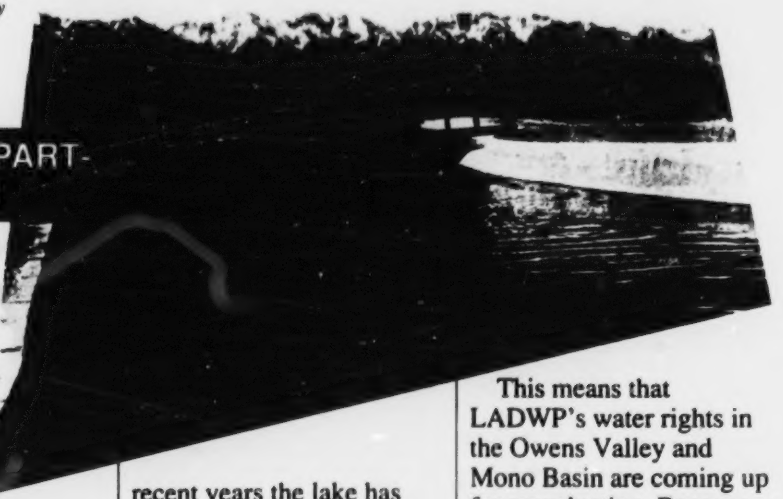
Because this water irrigates some of Mexico's best agricultural areas the water official is concerned that the U.S. live up to its agreement.

RESEARCH

Desalination

How does it work? How is the salt removed? What happens to the salt? How much energy does this process require? How near completion is the plant in Yuma? Is the process effective?





Los Angeles Aqueduct in the Owens Valley

DIRECTOR, LOS ANGELES DEPARTMENT OF WATER AND POWER

The agency responsible for obtaining water and energy for the city of Los Angeles is the Los Angeles Department of Water and Power (LADWP). In the early 1900s Los Angeles realized it was rapidly outgrowing its local water supplies and recognized the need to seek supplies far away. In 1905, the city of Los Angeles filed for water rights on the Owens River. The city built the 233-mile-long aqueduct from the Owens Valley, in the eastern Sierra Nevada, to Los Angeles. The aqueduct, capable of delivering four times as much water as the city then required, began service in 1913.

Today Los Angeles controls almost all the land on the valley floor, and 80 percent of the 600,000 acre-feet of water it delivers to its more than 3 million residents comes from the Owens Valley and adjacent Mono Basin. The rest comes from local ground water supplies and a small portion is provided by Metropolitan Water District's Colorado River and State Water Project supplies.

When MWD's Colorado River allotment is cut back, Los Angeles will also have reduced water supplies. So it too must look for additional water. Los Angeles was given permits in 1940 to divert water from four of the five tributaries feeding Mono Lake. As water has been diverted to Los Angeles, the level of Mono Lake has dropped. This naturally saline lake is twice as salty as the Pacific Ocean. Its Negit Island is an important nesting site for California gulls. In recent years the lake has declined by up to two feet per year in dry years, creating access to islands where coyotes have killed or driven off nesting gulls. The declining lake level has also exposed alkaline soil which has caused local air pollution.

In 1979 the National Audubon Society joined the Mono Lake Committee and filed a suit in state court against the Department of Water and Power for the City of Los Angeles. Eventually the California Supreme Court ruled that this area was to be considered under the doctrine of public trust, which holds that certain resources are the property of all citizens.

This means that LADWP's water rights in the Owens Valley and Mono Basin are coming up for reevaluation. Because they are going to be receiving less Colorado River water, LADWP hopes they will be allowed to keep and perhaps increase their water imports from the east side of the Sierras. Their only other source would be to buy more water from the State Water Project, an equally if not more expensive proposition.

D
W
P

Mono Lake

RESEARCH

The Owens Valley

How did the city of Los Angeles obtain the water rights to the Owens Valley? How is the land in this region used today? Is there continuing controversy about Los Angeles importing water from this area? Why? What compromises have been reached? How is LA and the Owens Valley tied to the Colorado River?

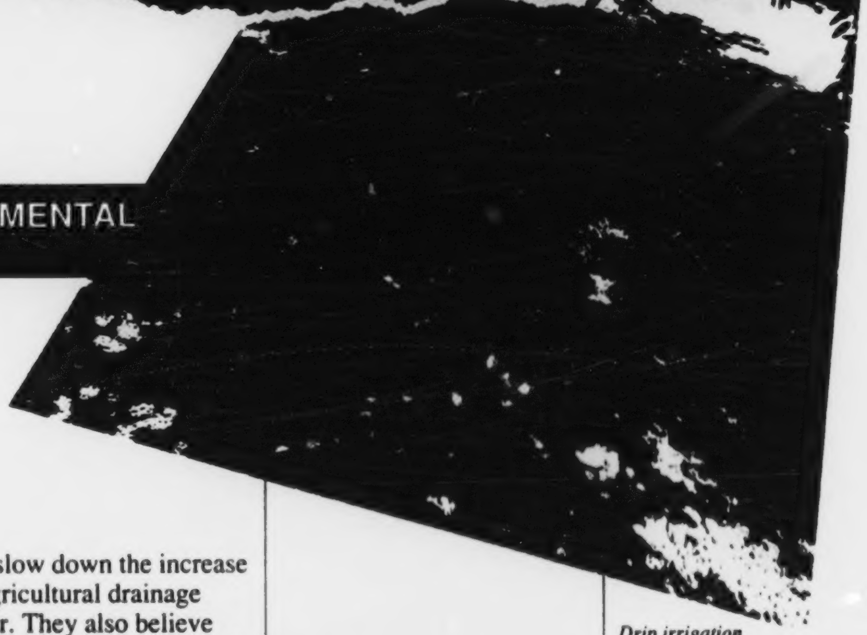
THE COLORADO RIVER CUT-BACK

ATTORNEY, ENVIRONMENTAL DEFENSE FUND

The Environmental Defense Fund (EDF) is a national environmental legal group with 8,000 California members. It tries to look for solutions to environmental problems that will protect the environment while satisfying social and economic needs.

EDF feels that water marketing, for example the exchange of financing of conservation programs by MWD in return for the IID water saved, would help increase the efficient use of water. It also would preclude the need to divert more water from northern California to southern California. EDF believes conservation is a cheaper and less environmentally damaging way to get more water than building new dams. The attorneys also favor increased efficiency of irrigation to save water and slow down the increase in agricultural drainage water. They also believe that agricultural land which is only marginally productive should not be cultivated or irrigated, both to save water and to reduce the salt build up in agricultural drainage.

EDF opposes the importing of more water from the Owens Valley and Mono Basin for Los Angeles. They feel the environmental cost to these areas of diverting more tributary waters is too great.



Drip irrigation

RESEARCH

Agricultural conservation of water

What are some ways that farmers can reduce the amount of water they use? How can agricultural drainage be reduced? Can water be reclaimed and treated for other uses?

VOCABULARY LIST

THE DELTA DILEMMA

estuary - the mouth of a river, in which the river's current meets the sea's tide

brackish - a mixture of fresh and salty water

marshland - a tract of low, wet land

aqueduct - a canal or conduit for carrying water for a distance

reservoir - a place where water is collected and stored for use, frequently behind a dam

habitat - the natural environment of an animal or plant

toxic - poisonous

phytoplankton - microscopic plant organisms, at the base of aquatic food chains

aquatic - having to do with water, as an aquatic environment

salinity - the amount of salt in water

THE KESTERSON CLEANUP

salts - combinations of common earth elements dissolved in the water and soil. The amount of salts dissolved in water is referred to as salinity.

ground water - water that is stored underground in sandy or porous soils called aquifers

surface water - water that is found along the surface of the earth in streams, rivers, lakes, etc.

agricultural drainage - the amount of irrigation water that does not soak into the ground, but is collected after the field has been watered

contaminated - not pure, not suitable for use because toxins (poisons) have been mixed in

water allocation - the amount of water set aside for or assigned to a certain agency or individual

aquifer - sandy soil that stores water underground

overdraft - to draw or pump more water out of an underground aquifer than is being replaced by water seeping in

selenium - an element commonly found in soil. Selenium is necessary for life in tiny amounts, but toxic in larger amounts.

wetlands - low-lying wet areas, marshes, usually surrounding fresh water, or formed as water evaporates from lakes

bioconcentration, bioaccumulation - concentration of a substance such as selenium as it moves up the food chain until it reaches levels which limit reproduction and causes death and deformities; usually first observed in bird populations.

migratory - going from one area to another, usually in large groups at certain times; as in migratory birds.

volatilization - the process of rapid evaporation at ordinary temperatures

THE COLORADO CUTBACK

litigation - a law suit or legal battle

entitlement - a certain amount of water designated by law as belonging to someone for their usage
conservation - the wise use of natural resources, like water

desalinization - the process of removing salt from water
percolation - the slow passage of water through porous soils

BIBLIOGRAPHY

This partial list of educational materials is to help you get started on your research topics. Many of them can be found in public or school libraries. Some can be ordered by teachers. The Water Education Foundation's booklets included in this packet may be duplicated by teachers.

BOOKS

A River No More: The Colorado River and the West
by P. Fradkin, 1981
America's Water
Conservation Foundation, 1984
Aqueduct Empire
by Erwin Cooper, 1968. California water development
The Bureau of Reclamation
by William Warne, 1973
The California Water Atlas
edited by William Kahrl, 1979. Basic sourcebook for all water facts
California Water: Looking to the Future
Department of Water Resources book 160-87, 1987
P.G. & E. of California
by Charles Coleman, 1952
The Salty Colorado
by T. Miller, G.Weatherford and J. Thorson, The Conservation Foundation, 1986
They Would Rule the Valley
by Senator Sheridan Downey, 1947 Classic history of the C.V.P.
The Thirsty Land
by Robert De Roos, 1948 History of the C.V.P.
Water
by Bill Guston, 1982
Water
by Leopold and Davis, Time Inc., 1972
Water, A Primer
by Luna Leopold, 1974
Water and Politics
by Vincent Ostrom, 1953
The Water Crisis
by D.S. Halacy, 1966
The Water Naturalist
by Heather Angel and Pat Wolesely
Water Pollution
by McCaull and Crossland, 1974
Water Resources
by John Mather, 1984. Use and management of water
Water Scarcity
Edited by Ernest Engelbert, 1986. Water and agriculture
Water, The Vital Essence
by Peter Briggs, 1967
Water, The Web of Life
by Hunt and Gerrels, 1972

ENCYCLOPEDIAS AND REFERENCE SERIES

Barnstead Series: Water
McGraw-Hill Encyclopedia of Science and Technology
Social Issues Resources Series (SirS)
reprinted articles organized by topics
The New Book of Popular Science
Grolier
Understanding Science Series
Sampson-Low

PAMPHLETS, VIDEOS, AND OTHER MATERIALS

Waterquest, a 28-minute video
Available from the Water Education Foundation
(916) 444-6240
Project Water Science - a series of water labs for high school
Water Education Foundation
(916) 444-6240
Western Water Magazine Reprint: "Where Your Water Comes From"
Available from the Water Education Foundation
(916) 444-6240
Layperson's Guide to California Water
Available from the Water Education Foundation
(916) 444-6240
H20 TV
Wastewater Treatment
Surface Water
All available from the Water Pollution Control Federation
(703) 684-2400
Wildlife Habitat Conservation Series
(Freshwater Marshes, Rivers & Streams , Wetland Conservation and Uses, Migrating Birds, Estuaries & Tidal Marshes) - Available from the National Institute for Urban Wildlife, 10921 Trotting Ridge Way, Columbia, ML 21044
Admiral Splash and Water for Ursa
Available free to teachers in the Metropolitan Water District of Southern California. In-service training required.
(213) 250-6739
The California Water Works, And Why It Does...
Department of Water Resources
(916) 322-3070
Profile of the Imperial Irrigation District, with water transport map.
Available free from the Imperial Irrigation District
(619) 339-9416

Regional Teacher's Guide Supplement
Available free from the Department of Water Resources
(916) 322-3070

Water Lifelines for Los Angeles
Available free to teachers in the City of Los Angeles from the Los Angeles Department of Water and Power
(213) 481-4169

Water: Where it Comes From and Where it Goes
Available from the East Bay Municipal Utility District, Oakland
(495) 835-3000

The Water Goes Round and Round
Available from the Santa Clara Valley Water District, San Jose
(408) 265-2600

Many other valuable resources are listed in the Water Education Curricula: A Compendium, available from the California Department of Water Resources (916) 322-3070

For more information on water and other informational materials contact:

Water Education Foundation
717 K Street, Suite 517
Sacramento, CA 95814
(916) 444-6240

ORDER FORM

		Qty. Ordered	$ Amount
Western Water Magazine	$20.00 yearly		
Back Issues	$2.50 each		
1989	**Title**		
• January/February	Flood Control		
• May/June	Water Marketing		
• July/August	Water Conservation		
• September/October	Contract Controversies		
• November/December	Wetlands Issues		
1990	**Title**		
• January/February	Growth Management		
• March/April	Conjunctive Use		
• May/June	The Drought Continues		
• July/August	Sacramento River Fisheries		
• September/October	Briefing on California Water Issues		
• November/December	The Endangered Species Act		
English California Water Map	$7.50 each		
Spanish Version California Water Map (100 or more $6.00 each)	$7.50 each		
Waterquest Video 1/2" VHS	$75.00 each		
Layperson's Guides	$3.50 each		
Layperson's Guide Set (10 or more of the same $2.50 each)	$30.00		

____ Agricultural Drainage
____ American River
____ California's Water
____ Colorado River
____ Delta
____ Drinking Water
____ Flood Management
____ Ground Water & Toxics
____ New Melones Dam
____ San Francisco Bay
____ Water Conservation
____ Water Quality
____ Water Reclamation
____ Water Rights Law

		Qty. Ordered	$ Amount
Guidebook: "Where Your Water Comes From"	$3.00 each		
New Homeowners Landscape Brochure	$1.00 each		
Landscape Renovation Brochure	$1.00 each (250 or more .75 each) (500 or more .50 each)		
Water Awareness Stickers - 12 to a sheet	$0.25 per sheet		
Hydrologic Cycle Poster	$2.00 each		
English Version Trivia Game	$1.00 each		
Spanish Version Trivia Game	$1.00 each		
"I'm Water Aware" Pin	$2.00 each		
Slide Show	$200.00 Purchase		
"Making California's Water Work"			
School Programs			
• "California Water Story" – Upper Elementary Unit	$15.00/set		
• "Project Water Science" – Secondary Level	$15.00/set		
• "California's Water Problems" – Middle School Level	$15.00/set		
	Subtotal		
Be sure to add 6.75% California sales tax to your order	+6.75% Tax		
Shipping & Handling:	$0-$50 – $1.50 • $51-$100 – $5.00 • $101 & over – $10.00		
	TOTAL		

Name: ______________________________

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Water Education
FOUNDATION

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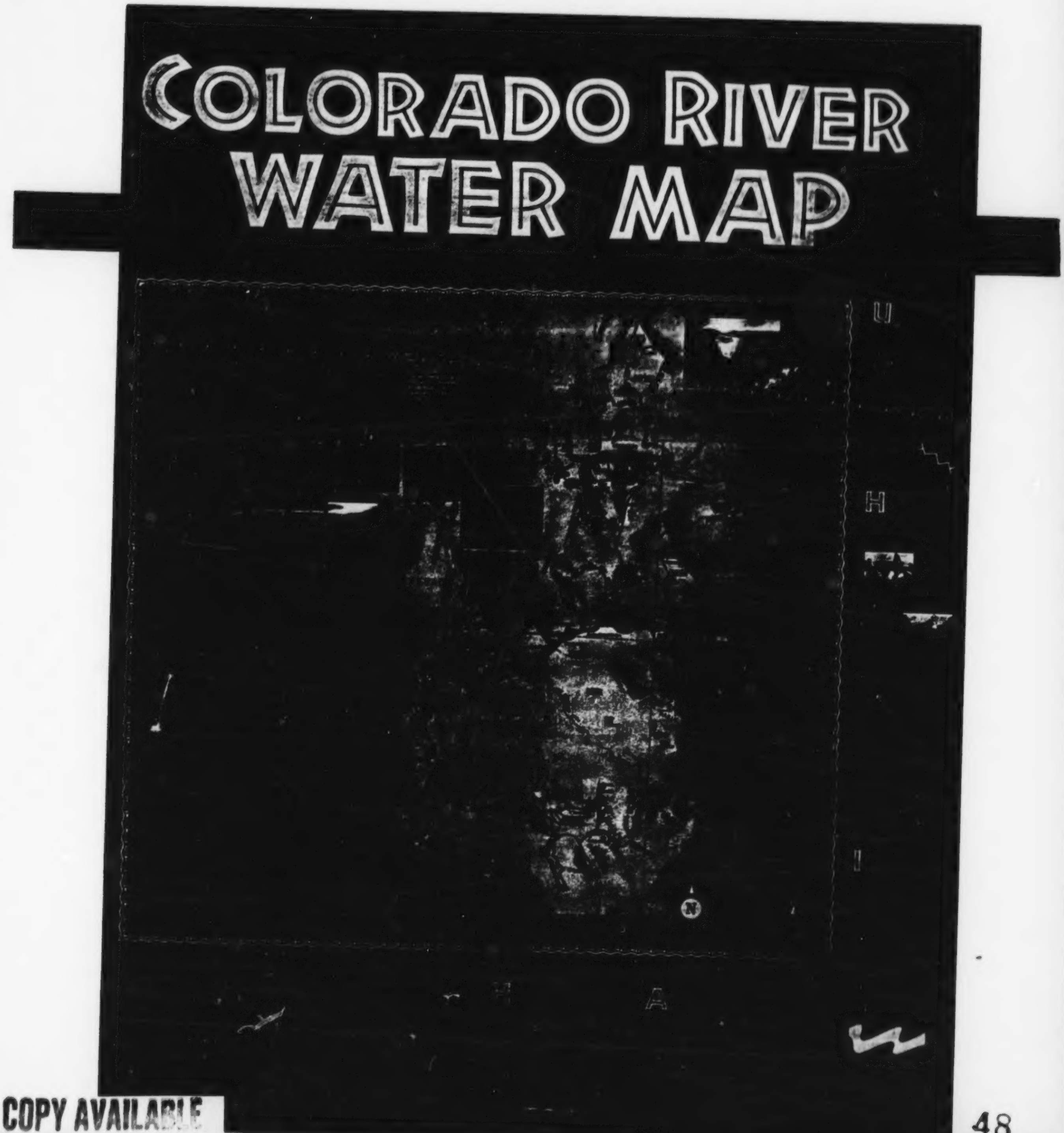
Sacramento, CA 95814
(916) 444-6240

Layperson's Guide to the Colorado River

Prepared by the Water Education Foundation


COLORADO RIVER
WATER MAP
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The Painted River 14

Unresolved Issues 16

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1991
On the Cover
Hoover Dam on the Colorado River.

Printer: Paul Baker Printing

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Introduction

The steep and turbulent Colorado is one of the country's most dramatic rivers. It falls more than 10,000 feet in its course from the Rocky Mountains to its natural outlet in the Gulf of California. From where it begins as a small stream northwest of Denver to where, most years, it dies on broad dry lands before reaching the Gulf, the river has carved some of the world's most magnificent gorges, including the awesome, mile-deep Grand Canyon. Since water is so precious in the arid lands it passes, rifts of disagreement almost as deep as the canyon have had to be spanned in a century of efforts to agree on division of the water.

The Colorado supplies water to 17 million people and more than one million acres of once-desert farmland. Part of the food Westerners consume and much of southern California's electricity is a product of the Colorado River. The river's hydroelectric plants generate about 12 billion kilowatt-hours of electricity each year, more than half the amount needed to supply the city of Los Angeles. Besides water for man's use, the river provides stretches of wilderness which offer a spiritual resource for many people. Six national parks and recreation areas provide entertainment for millions of vacationers who fish, raft, boat and swim in the river and its reservoirs. They also camp along its banks, hike its wilderness areas and tour its dams and canyons. Whitewater rafting attracts thousands of visitors each year, and the river's turbulent rapids are considered by many to be the ultimate kayak trip.

Balancing the water, power and recreational demands on the Colorado River—assuring needed flood control and protecting water quality—has become critical in recent years. As mountain springs and melting snow form rivulets at the sources of the river, each drop is already planned for by a water user downstream. The Colorado is one of the nation's first major rivers to reach the point where its entire flow is fully apportioned. As such, it has become a focal point of debate for water supply and environmental issues throughout the nation and the world. How we manage the Colorado may hold solutions for future balancing of our finite water resources against ever-increasing demands and needs. In this decade, California will lose part of its entitlement to the Colorado River, (from 5.3 to 4.4 million acre-feet) because of a 1963 Supreme Court decision. Coastal southern California will lose about half of its supply, about 600,000 acre-feet. It will have to make up this loss with northern California water, a source of controversy, and vigorous conservation programs. Competition for the Colorado River affects decisions concerning the Sacramento-San Joaquin Delta, the north coast rivers and Mono Lake.

For the developing West, the Colorado was a promising frontier in water development. The river could bring life and prosperity to any arid land its water reaches by canal or aqueduct. Now it is a frontier of a different nature. The challenge today is to limit the demands, or to extend the resource to serve more needs with the same amount of water. The only other possibility is to increase somehow the amount of water available.

The Colorado River has a huge drainage basin that covers 244,000 square miles of the country's hottest and driest lands. The river is 1,440 miles long and passes through parts of seven states (Wyoming, Colorado, Utah, New Mexico, Arizona, Nevada and California) and the Republic of Mexico. These seven states are called the basin states. The basin includes about one-twelfth the area of the mainland United States—almost the entire southwest corner. For much of this area, the Colorado River is the only reliable source of water. It is aptly called "the lifeline of the Southwest." This lifeline cannot be extended to all the areas that are dry. Some land will remain a barren plain or uninhabitable desert. Despite its length and the size of the watershed, the Colorado ranks only about sixth among the nation's rivers in volume of flow. Its long-term dependable average annual flow is only about 14 million acre-feet, less than the Sacramento River. By comparison, the Delaware River is only 390 miles long and drains a basin of 12,400 square miles. The Columbia River's drainage basin is of comparable size to the Colorado's, but its flow is about 12 times greater than the flow of the Colorado.

Demands on the Colorado are not limited to needs in its basin. In fact, more water is exported from the Colorado's basin than from any other river basin in the United States. Water is diverted over the Continental Divide into eastern Colorado and on to supply the city of Denver. Water is diverted in Utah to the Salt Lake Valley and in New Mexico to the Rio Grande River basin to serve Albuquerque and the central part of the state. In California, Colorado River water is diverted to serve southern coastal and desert areas of the state from north of Los Angeles to the Mexican border. By the end of the century almost every drop of the Colorado River will be accounted for. If there are droughts or large-scale developments or transfer of rights, that day could come sooner. The river has been called the most apportioned and institutionalized in the United States.

This guide traces the history of development of the Colorado River and summarizes the difficult bartering and compromising that have resulted in dividing the waters among the basin states and Mexico. The concluding section explains the problems and decisions faced today in managing the Colorado to provide for the use, protection and preservation of this essential resource.

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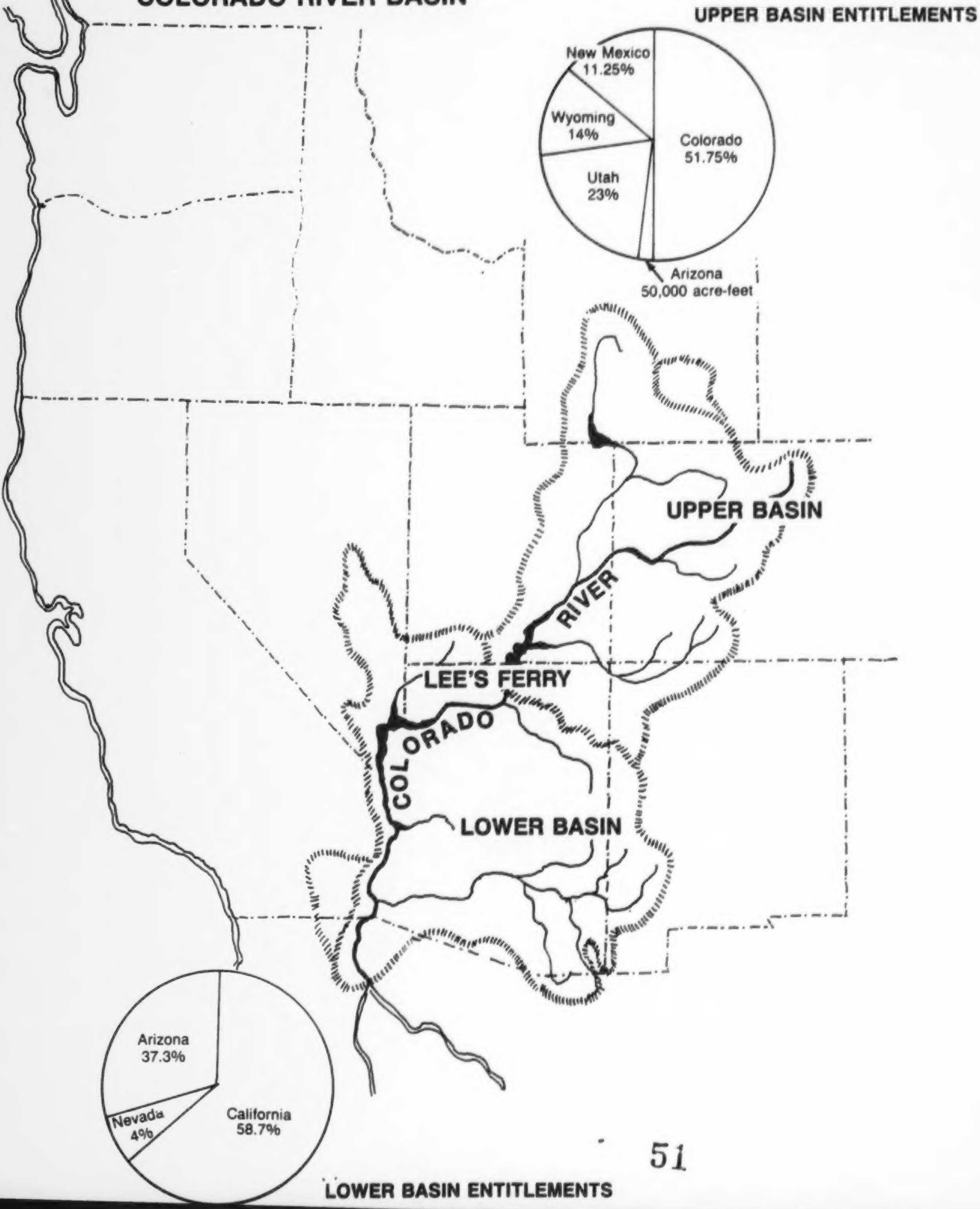
COLORADO RIVER BASIN


UPPER BASIN ENTITLEMENTS
New Mexico
11.25%
Wyoming
14%
Utah
23%
Colorado
51.75%
Arizona
50,000 acre-feet
UPPER BASIN
RIVER
LEE'S FERRY
COLORADO
LOWER BASIN
Arizona
37.3%
Nevada
4%
California
58.7%
LOWER BASIN ENTITLEMENTS

History

The earliest development of the Colorado to serve man's needs was by ancient Indians. The Anasazi Indians of the Chaco Canyon, in the desert of northwestern New Mexico, were an advanced culture dating from 600 A.D. By the 12th century, they had a well-developed civilization with a complex water distribution system. At the height of their civilization, it has been estimated that five to ten thousand people occupied communal dwellings in the canyon.

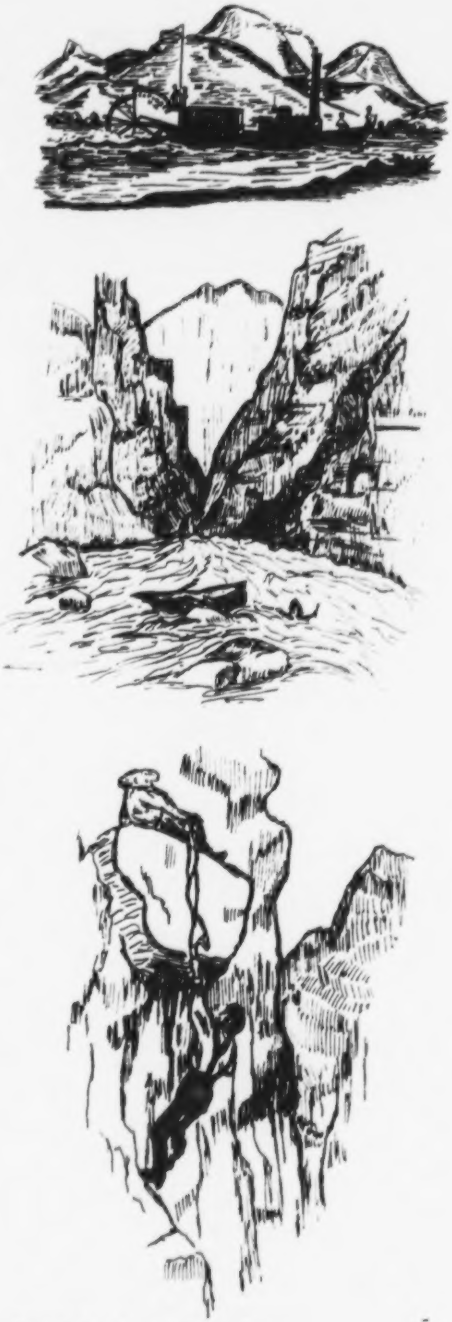
Contemporaries of the Anasazi in the lower basin, the Hohokam Indians of Arizona, are believed to have had an even older civilization. Though not as advanced in their water system, the Hohokam Indians also built extensive ditches and canal systems to divert water from the Colorado. At the Montezuma Well in central Arizona, canals built by the Hohokam are preserved in almost original condition because of their lime linings created from the calcium content in the water.

There was some exploration and settlement of the Southwest by the Spanish in the sixteenth century. The early Spanish explorers were primarily interested in treasure and were discouraged by the ruggedness of the terrain and the failure to find riches. A few Spanish settled areas of Arizona and New Mexico. The Spanish introduced livestock and built dams and reservoirs, as well as diversion ditches and canals.

The Colorado River basin was the last major area of the 48 mainland states to be explored by Anglo-Americans. It appeared on United States maps in the 1850's as an area more than 500 miles long and 200 miles across marked "unexplored." Eastern Congressmen called this omission "inexcusable ignorance of our own country." They could not have imagined the height and ruggedness of the Rocky Mountains, the turbulence and steepness of the river, nor the depths and inaccessibility of its canyons. This terrain was vastly different from the basins of the Mississippi or the Ohio, where navigation of the rivers aided exploration.

Much of the California coast was explored by ships, but ships could not travel up the Colorado River, even if they managed to get safely into the channel. Spanish explorers, and those who followed them, encountered a severe tidal bore that endangered and sometimes capsized their ships. The rising tide entering the narrow channel from the Gulf of California caused sudden surges of water that moved up the river. The severity would depend on the lunar influence. There were reports that the large wave traveled at high speed up the river with a loud roar. This phenomenon, which occurs in wide-mouthed bays with narrowing channels, cannot be confirmed today because no water from the Colorado has reached its natural outlet in the Gulf in more than 20 years, except during floods in 1980, 1983 and 1984.

The U.S. Army-Ives Expedition of 1857-58 traveled 420 miles up the mouth of the Colorado River; however, it was 1869 before the Colorado basin had been fully explored. In that year, the geologist, John Wesley Powell, a one-armed Civil War major, floated down the Colorado through the Grand Canyon, proving for the first time that it could be done. He published a detailed account of his exploration in 1875 and achieved the notoriety to later become director of the U.S. Geological Survey. Based on his exploration, Powell believed large-scale development of the Colorado was impractical because there was not adequate water to serve the arid lands of the region. But he believed a limited amount of development, under federal auspices, was feasible.



(Top) Lt. Ives' Steamboat Explorer 1858. (Middle) The Wreck of the No Name during Powell's first expedition. (Bottom) Powell rescued via a companion's "underdrawers" while exploring a canyon.

Dividing the Waters 5

The Colorado is often described as the most controversial and regulated river in the country, perhaps the world. Considering the importance of water to all of the Southwest, it is not surprising that there was—and still is— controversy over how this single major river is to be shared by seven arid states, several Indian tribes and the Republic of Mexico. What is perhaps more surprising is that it has been possible to come to any agreement at all.

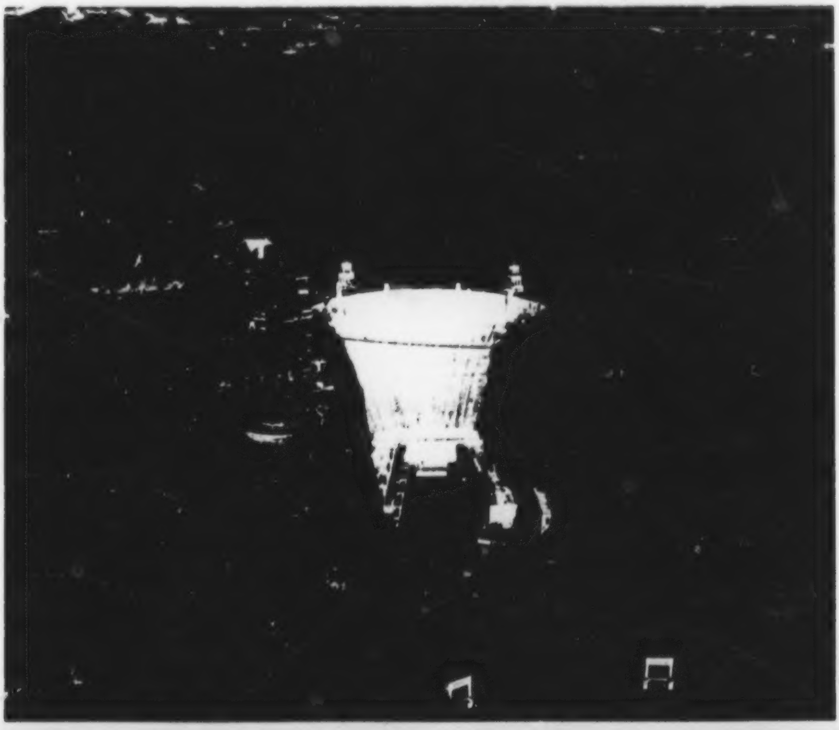
There are vast deserts and arid plains in all of the seven states. Without water, this land cannot be developed. Some of the states could make, ultimately, full use of most of the water in the Colorado River by themselves. In Arizona, for example, the available land resources exceed water resources by at least a hundredfold. The land in all the states which could benefit from water for irrigation far exceeds available capacity of the Colorado River.

Because of the tremendous water needs throughout the basin states, building any large project on the Colorado has always involved barter and compromise. When the first projects were built, it was in the atmosphere of a developing country anxious to settle its wilderness. Today, the dominating influence is the fear of overdevelopment. But throughout this century, one factor has remained constant: Mexico and each state and each Indian tribe wants to assure its own share of the water.

In view of the scarcity of water and the political realities of the West in its developing years, it is hard to imagine how this controversy and litigation over the Colorado could have been avoided. A stronger federal role is unlikely to have been accepted. The western states have traditionally fought federal control over the states' resources, particularly water. The West's fierce independence and strong convictions regarding states' rights were even more extreme at the turn of the century than they are now.

Apportionment of the water and agreements to support projects were hammered out by determined, desperate people, because each concession of more water—or a project—for one area meant deprivation for another. No state's representative could go home from the bargaining table with less than what it was thought possible to obtain and expect to survive politically. Most of the agreements were worked out through a balancing of mutual self-interest and bargaining.

Concern over development of the Colorado began with the development of the American West. Because of the 1849 gold rush, California was settled more rapidly than other western states. As development progressed, settlers began to think of the farming that would be possible in the rich desert lands. In some areas of the Rocky Mountains, the growing season between frosts was as short as two months while in the southern California desert there was a long growing season conducive to growing as many as three consecutive crops a year, if water could be brought to the land. The only source within a feasible distance was the Colorado River.



Hoover Dam, a monumental project built after years of negotiation and compromise, backs up the Colorado for flood protection, water storage for municipal and agricultural uses, hydroelectric power generation and other uses.

Chronology

Year	Action or Event	Significance or Result
1849	Dr. Oliver Wozencraft conceives idea of irrigating Imperial Valley	Land grant request refused by Congress
1857	Lt. Joseph C. Ives, U.S., in the Steamboat "Explorer" begins exploration of Colorado River from its mouth to present site of Hoover Dam, 420 miles	
1865	Lower Colorado lands first set aside for Indians	
1869	John Wesley Powell explores the Colorado through the Grand Canyon by wooden boat	Later became director of U.S. Geological Survey, and opposed the Reclamation Movement of the 1890's.
1875	Powell issues his report on exploration of the Colorado	
1877	Thomas Blythe secures 40,000 acres in the Palo Verde Valley and files for one of the first diversions from the Colorado	
1888-89	Extreme drought and cattle losses hit the West	
1892	Grand Ditch completed — 16.7 miles long — first major diversion outside the basin, conveys water across the Continental Divide into eastern Colorado	Precedent for inter-basin transfers
1900	Basin's population is 260,000	
1901	100,000 acres irrigated in California's Imperial Valley	
1901	Santa Fe Railroad completes tracks to south rim of the Grand Canyon	Canyon becomes tourist attraction
1902	Newlands Act passed	Establishes the U.S. Reclamation Service
1902	Arthur Powell Davis unveils comprehensive development plan for the Colorado River	
1905-07	Colorado River breaks through Imperial Valley Canal headgates	Entire flow of the river passed into the Imperial Valley destroying homes, agricultural lands and creating the Salton Sea
1908	*Winters v. U.S.* decision — Supreme Court reserves water, as well as land, for Indian reservation	(1917) Last lower basin lands reserved for the Indians
1909	160,000 acres are irrigated in the Imperial Valley	
1910	Mexican Revolution	Unsettled conditions threatened canal
1911	Imperial Irrigation District formed	
1913	Los Angeles Aqueduct from Owens Valley completed	
1919	Congressman Kettner from San Diego introduces bill authorizing construction of the All-American Canal	(1916) 300,000 acres under cultivation in the Imperial Valley

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Year	Action or Event	Significance or Result
1919	Creation of Grand Canyon National Park, reserving a 132-mile reach of canyon and river for the public	
1920	Los Angeles population reaches 600,000	Los Angeles looks to Colorado for power production, city council endorses Davis Plan
1920	Kinkaid Act authorizes government to collect data about All-American Canal and plans for potential reservoir introduced (Davis Plan for dam on Colorado)	 *Construction of MWD's Parker Dam*
1920	Colorado attorney Delph Carpenter argues for Colorado River Compact	
1920-21	Basin states and Congress approve idea of Compact	
1922	Supreme Court rules in *Wyoming v. Colorado* that appropriative doctrine applies regardless of state lines ("first in time, first in right")	
1923	All basin states except Arizona ratify Compact	
1924	Southern California cities and other agencies begin to form the Metropolitan Water District of Southern California (MWD) to build eventually the Colorado River Aqueduct	
1925	Six state compact arrangement approved by Nevada and upper states, California approves contingent on construction of a high dam on the lower river	
1927	California legislature approves MWD and authorizes it to provide a supplemental water supply to the coastal plain of southern California	Gave support to the Imperial Valley interests in efforts to develop Colorado River
1928-29	Boulder Canyon Project Act approved by Congress, Compact also approved as part of Boulder Canyon Project Act	California agrees to limitations of the Act
1929	President Hoover declares Boulder Canyon Project Act in effect	
1929	Great Depression begins	
1929-30	U.S. and Mexico negotiate towards apportionment of Colorado River, U.S. offers Mexico 750,000 acre-feet annually	No agreement reached
1930	California agrees to purchase all power produced by Boulder Canyon Project	
1930	First *Arizona v. California* case filed to invalidate Boulder Canyon Project Act	
1932	Construction of Boulder (Hoover) Dam started	

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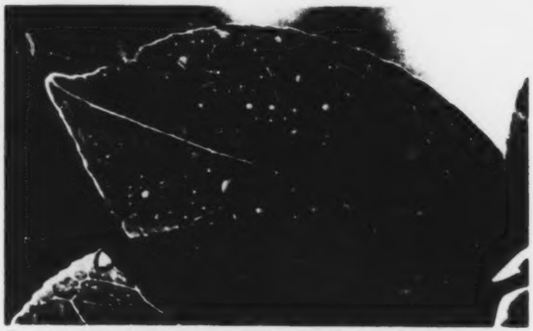
Year	Action or Event	Significance or Result
1932	Grand Canyon National Monument created	
1933	Arizona sends National Guard to prevent construction of diversion by MWD to coastal southern California	
1934	Second *Arizona v. California* case filed to invalidate Boulder Canyon Project Act	
1935	Arizona requests judicial apportionment of lower Colorado	Supreme Court refused on technical grounds; U.S. not a party to the suit; Arizona would have to show deprivation of actual rights
1936	Third *Arizona v. California* case filed to invalidate Boulder Canyon Project Act	
1937	Congress approves Colorado-Big Thompson Project	
	National Resource Drainage Basin Report is published	
	California creates Colorado River Board to protect its interests in the river	
1939	Bureau of Reclamation establishes power line from Hoover Dam to supply Arizona with emergency power	Leads Arizona to reconsider policies against Compact
1940	Arizona reassesses water policy	Reconsiders opposition to Compact
1941	242-mile long Colorado River Aqueduct is completed by MWD and begins delivering water	Funded by a $220 million bond issue, this was the last major water system to be built in California by a city or municipal district without state or federal funding
1942	Imperial Valley receives first deliveries via All-American Canal	
1944	U.S. and Mexico sign treaty giving Mexico 1.5 million acre-feet of Colorado River water annually (slightly less than Mexico was believed to be using)	
1944	Arizona legislature ratifies Colorado River Compact (after 22 years of opposition)	
1945	Senate ratifies treaty with Mexico	
1946	Reclamation Bureau issues study called for in Boulder Canyon Project Act	Concluded there was not enough water for all projects proposed; Congress refused to approve any projects until upper states determined their individual rights
1946	Upper basin states authorize the negotiation of Compact to apportion their share of the river	
1947	Colorado River water is delivered to San Diego via MWD	

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Year	Action or Event	Significance or Result
1947	Reclamation Bureau presents plans for Central Arizona Project (CAP)	
1948	Upper basin negotiations result in apportionment, formal signing in Santa Fe, creation of Upper Colorado River Commission	Paved the way for new projects in upper basin
1949	Water is delivered to Coachella Valley	
1949	States and Congress approve Upper Colorado River Basin Compact	
1950	Reports of President's Water Resources Policy Commission with plans for Colorado River	
1951	Congress refuses to approve Central Arizona Project (CAP) until differences between California and Arizona are resolved	(1952) Arizona files suit asking court to apportion lower basin water
1952	Bill for projects on upper Colorado meets nationwide opposition because of plans to flood Dinosaur National Monument	
1956	Colorado River storage project bill is approved by Congress, also authorizes Glen Canyon Dam	
1961	Welton-Mohawk Irrigation District completes drain discharging salty water to lower Colorado above Mexico's intake	Crop losses from salinity cause protests from Mexico and conflicts over water quality not specified in 1944 treaty
1962-64	New upper basin projects are authorized by Congress	
1963	*Arizona v. California* decision: U.S. Supreme Court apportions lower basin allocation	**MWD of So. Ca. to lose approximately 600,000 acre-feet of Colorado River water when the Central Arizona Project goes on line (1985)**
1963	Glen Canyon Dam is completed	
1964	Bureau of Reclamation completes Pacific Southwest Water Plan	
1965	Water is discharged from reservoirs to improve water quality in Mexico, Welton-Mohawk drain discharge is relocated	
1967	Navajos agree to limit upper Colorado claim to 50,000 acre-feet in exchange for power plant	
1968	Colorado River Basin Project bill is approved by Congress, proposed Grand Canyon Dam is eliminated from bill after one of the biggest environmental battles in U.S. history	
1968	Ten-year federal moratorium on studies to bring water from other basins is imposed	

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Year	Action or Event	Significance or Result
1968	National Research Council report on "Water and Choice in the Colorado Basin" is published	
1973	Minute 242 of International Boundary Commission is signed by Mexico and U.S.	Specified salinity limits for water to Mexico
1974	Colorado River Basin Salinity Control Act is approved by Congress	Authorized salinity control projects in Nevada, Utah, Colorado and one of the largest desalination plants near Yuma
1978	Ten-year moratorium on studies to bring water from other basins extended another ten years	
1979	Supreme Court turns Indian irrigation disputes over to Special Magistrate	(1982) Special Magistrate recommends Indian claims be upheld
1980	Arizona passes Ground Water Management Act which sets a broad goal of cutting the state's per capita water consumption in half by the year 2025, mainly by reducing agricultural consumption	
1983	*Arizona v. California:* Supreme Court refuses to reopen 1964 decree awarding federally reserved water rights to five lower basin tribes	Supreme Court rejects Special Magistrate's recommendation that Indian claims be upheld, other Indian rights cases pending
1984	Amendments to 1974 Colorado River Basin Salinity Control Act	Added an on farm salinity control program and non-federal cost sharing
1984	Hoover Power Plant Act of 1984	Authorized increased capacity (uprating) of Hoover Power Plant generators
1985		California's water allotment reduced from 5.3 to 4.4 million acre-feet when CAP starts MWD of So. Ca. loses approximately 600,000 acre-feet dependable supply because the Central Arizona Project is now on line. However, the Secretary of the Interior can allocate Colorado water to California in years of surplus
1986	Colorado River Floodway Protection Act	Defined floodway to minimize loss of human life, protect health and safety, and minimize damage to property from Davis Dam to the Mexican border
1986	Lower Colorado Water Supply Act	Provides for water supply to non-agricultural water users in California with limited or no rights to Colorado River water
1987	Hoover Dam power contracts renewed	
1988	Central Arizona Project officially reaches Phoenix	
1991	Central Arizona Project to reach Tucson	
1993	Scheduled completion of Yuma desalination plant	

The Lifeline

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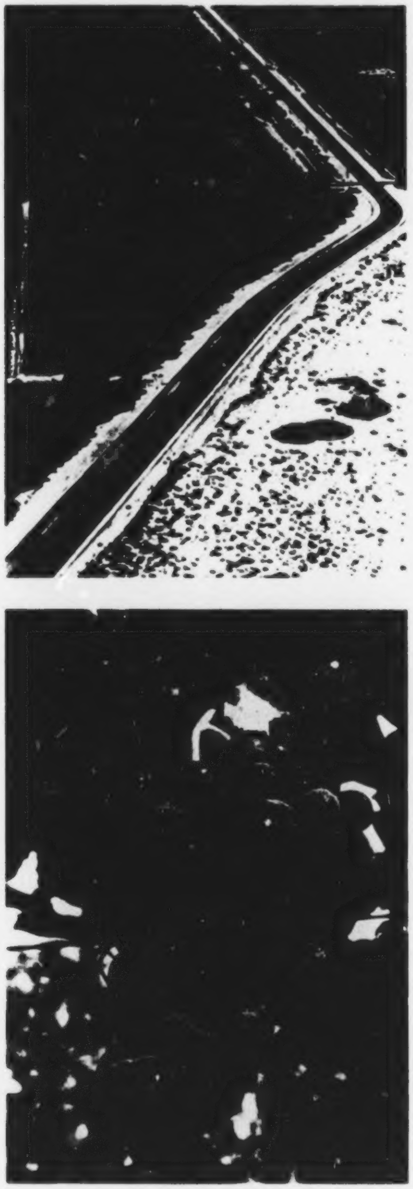


(Top) Irrigation today in the Imperial Valley. Colorado River water is delivered through the All-American Canal. (Below) Grapes in the Coachella Valley. Colorado River water is delivered through the Coachella Canal.

As California developed lands for agriculture, other states in the basin began to fear that they would lose their rights to the water by the time their development caught up with California's. All western states recognized the doctrine of appropriative rights which was the prevailing water law in most mining areas of the world. The doctrine held that the first to use the water established the first rights to use it, or "first in time, first in right." If California established priority rights by using large amounts of the Colorado's flow, the other states might be forced to leave enough water in the river to satisfy those rights.

California's first irrigation of the Imperial Valley was by a canal, an old overflow channel of the river that went through Mexico. Mexico allowed American settlers to use the diversion in exchange for half the water. Users of the canal were dissatisfied with Mexico's control over their water supply and had conflicts over maintenance of the levees. They also feared that Mexico's use of the water would increase. The users wanted to build a canal from the Colorado that was entirely within the United States to be called the All-American Canal. For a project of this size, federal help was needed.

There was little chance of getting Congress to approve any large project on the Colorado without the support of all the states in the basin. This created a stalemate for any large projects. None of the other basin states would approve a project that would allow one state to establish rights to Colorado River water without getting similar projects of their own.

In the first two decades of this century, a number of events occurred that increased the motivation to break this stalemate. The United States Reclamation Service was established in 1902 and the reclamation movement began with the goal of developing regional water supplies for farming and flood control projects sponsored by the federal government. It's leader, Arthur Powell Davis, nephew of John Wesley Powell, conceived a comprehensive plan for developing dams and reservoirs on the Colorado River.

In 1905, flood waters broke through the headgates of the Imperial Valley Canal. The entire flow of the Colorado poured into the Imperial Valley destroying homes and thousands of acres of agricultural lands and creating the Salton Sea. The Southern Pacific Company, owner of the irrigation works, finally repaired the break after working for two years. A railroad trestle was built across the break, and carloads of rock, gravel, and clay were dumped from trains to form a dam. This disastrous flood intensified the push for the All-American Canal, and the Mexican Revolution of 1910 gave it further impetus. Proponents of the canal eventually joined with Davis to support his broader program of dams and reservoirs which was expanded to include the canal.

As pressure was increasing for these projects and for flood control on the lower Colorado, Los Angeles was seeking a power supply for its growing population. The potential for hydroelectric power development made the city a natural ally of the proposal for a large dam on the lower Colorado.

In 1920, Delph Carpenter, a Colorado water rights attorney, proposed the idea of an interstate compact. The timing was excellent for the basin states to be receptive to the idea of negotiating their differences. California wanted its projects and would have a better chance to get them with support from other basin states. The other states were afraid the projects would be approved because of strong arguments for flood control, and they wanted their own interests protected.

Negotiations

The state legislatures of all the basin states and the federal government approved the concept of a compact, and negotiations began in January, 1922. The meetings of state and federal representatives, called the Colorado River Commission, were chaired by the Secretary of Commerce, Herbert Hoover.

The negotiators were not able to resolve all the issues they had attempted, but reached an agreement to divide the watershed into upper and lower basins and apportion the right to use 7.5 million acre-feet per year to each basin. All the delegates signed the Compact, but it had to be ratified by Congress and the legislatures of all the states involved. Arizona's legislature refused to ratify the Compact.

Finally, unable to secure Arizona's approval of the Compact, the remaining states endorsed a six-state compact. California approved the six-state agreement on the condition that a high dam would be built on the lower Colorado.

The Boulder Canyon Project Act was then introduced in Congress, with provisions for a six-state or seven-state compact incorporated into the agreement. The upper basin states did some bargaining of their own and agreed to support the bill only if California would agree to limit its use of Colorado River water. Although Arizona was not a party to the compact, the upper states wanted some assurance that Arizona's later claims to the Colorado would come from the lower basin's share, and not from their share.

When the Boulder Canyon Project Act was passed, it contained a suggested lower basin apportionment restricting California's use to 4.4 million acre-feet and no more than half of any surplus water. When the California legislature approved this limitation, the Act was declared effective. California also had to agree to purchase all the electricity from the power plant before Hoover Dam could be built.

Conflict between Arizona and California continued long after Hoover Dam and the All-American Canal were completed. In 1931, 1934 and 1936, Arizona appealed to the Supreme Court to resolve the states' differences, each time unsuccessfully. There was little to support Arizona's claims of damage with California's limitation of use and with surplus water in the river.

Arizona's water policies began to change in 1939 when it became necessary for the state to accept power from Hoover Dam for the first time. Finally, in 1944, the Arizona legislature ratified the Compact. Then Arizona began efforts to secure federal projects of its own.

In the upper basin, projects authorized for study in the Boulder Canyon Project Act were blocked until the states determined their individual rights. In 1948 these states reached an agreement that apportioned percentages of the flow available to the upper basin and 50,000 acre-feet to the small portion of Arizona that was in the upper basin. The agreement also established the Upper Colorado River Commission to determine water use in each upper basin state if diversions had to be reduced to meet lower basin entitlements.

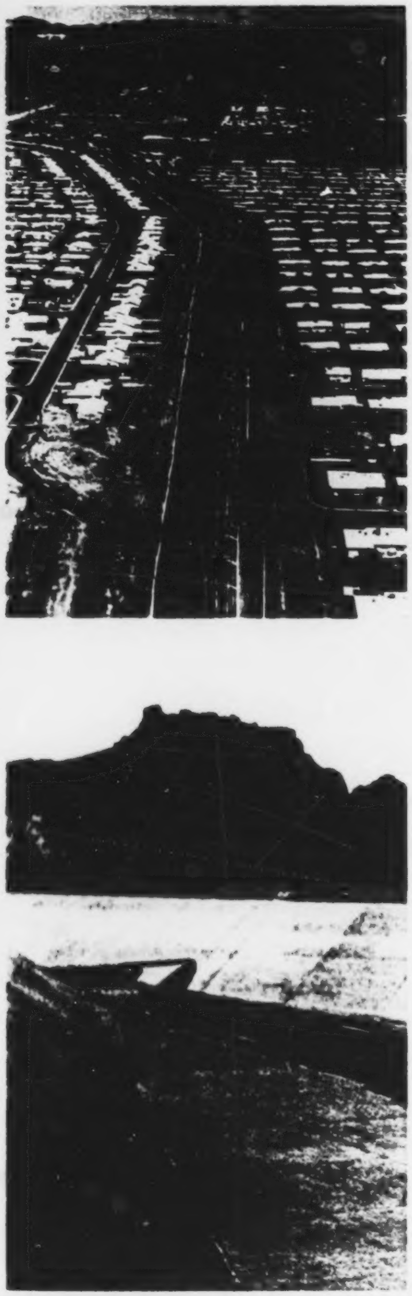
In 1952 the first bill for projects on the upper Colorado met with nationwide opposition because of plans to flood the canyons of Dinosaur National Monument. These canyons are on the Green River, a tributary of the Colorado. The Flaming Gorge Dam was substituted for the proposed Echo Park Dam, and the Colorado River Storage Project Act of 1956 was approved by Congress. This act authorized the Glen Canyon Dam to be built just above Lee's Ferry near the Arizona-Utah border. It also authorized the Central Utah Project and 11 projects in Wyoming, Colorado and New Mexico. Several other upper basin projects were authorized in 1962 and 1964.

While other states were obtaining water projects, Arizona's plans for an aqueduct to carry water to Phoenix and Tucson were stalled. Congress would not approve the Central Arizona Project (CAP) until Arizona's share of the Colorado was determined. Arizona again appealed to the Supreme Court, this time to apportion the water among the lower basin states. The Court determined that Arizona had a legitimate cause, and the case was litigated for 11 years before a decision was reached. The resulting 1963 decision gave a surprising interpretation to the Boulder Canyon Project Act. The Court said that Congress had empowered the Secretary of the Interior not only to suggest, but to implement the lower basin agreement suggested in the Act. Further, the decree held that the Secretary of the Interior also had been empowered to determine how future shortages would be apportioned among the states.

This controversial decision advanced, for the first time, the view that Congress had the power to apportion rights to interstate streams. It also asserted that Congress had empowered the Secretary of the Interior under certain conditions to apportion water rights of the Colorado River. The decision initially gave Arizona everything it had wanted in the initial Compact negotiations. It also cleared the way for the CAP. California's water allotment would be cut eventually from 5.3 million acre-feet to 4.4 million acre-feet. Coastal southern California lost more than 600,000 acre-feet of water entitlement in 1985 through Metropolitan Water District of Southern California (MWD), although presently MWD reserves surplus water.

Despite its Supreme Court victory, Arizona still found it necessary to bargain with California and the upper basin states to get its project through Congress. Arizona agreed, in event of shortages, to limit diversions to the CAP to assure delivery of the 4.4 million acre-feet apportioned to California.

he Law of the River 13



(Top) The Bureau's 1903 Salt River Project winds near the developing Phoenix area. Both Phoenix and Tucson will be served by the Central Arizona Project (CAP). (Below) The CAP under construction near Phoenix.

The Colorado River has been apportioned among the seven basin states and the Republic of Mexico by a number of interstate agreements, contracts, an international treaty, state and federal legislation, a Supreme Court decision and federal administrative actions. These various documents and laws are known, collectively, as "The Law of the River."

Among the documents forming "The Law of the River," some of the most significant are:

1. The Colorado River Compact of 1922, which divided the rights to the water between the upper and lower basins, with the dividing line and measuring point near Lee's Ferry

2. The Boulder Canyon Project Act of 1928, which authorized construction of Hoover Dam and Power Plant and the All-American Canal

3. The Mexican Water Treaty of 1944, in which the U.S. agreed to deliver 1.5 million acre-feet of Colorado River water to Mexico annually

4. The Upper Colorado River Basin Compact of 1948, which apportioned the upper basin share of water among the upper basin states

5. The Colorado River Storage Project Act of 1956, which authorized several storage reservoirs in the upper basin

6. The *Arizona v. California* Supreme Court decision (June 3, 1963) which determined the lower basin apportionment among Arizona, California and Nevada

7. The Colorado River Basin Project Act of 1968, which authorized the Central Arizona Project (CAP) and limited diversions to the CAP during shortages to assure California's entitlement of 4.4 million acre-feet annually. This federal act also established the priority of satisfaction of the Mexican Water Treaty as the first call on any future augmentation project, and directed the Secretary of the Interior to propose criteria for the coordinated long-range operations of federal reservoirs on the Colorado River

8. The "Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs of 1970," which provided for the storage of water in reservoirs of the Colorado River Storage Project and set a priority for release of water from Lake Powell

9. The Federal Water Pollution Control Act Amendments of 1972, which gave the U.S. Environment Protection Agency authority to control water quality of the nation's rivers

10. Minute 242 of the International Boundary and Water Commission, United States and Mexico, issued in 1973, which required actions to reduce the salinity of water delivered to Mexico

11. The Colorado River Basin Salinity Control Act of 1974 and 1984 amendments, which authorized desalting and salinity control projects to improve Colorado River water quality

All dams on the Colorado River are operated by the Bureau of Reclamation, an agency of the U.S. Department of the Interior. The Secretary of the Interior makes the decisions which control distribution of the water from these projects. The Interior Secretary's decisions are to be in accordance with all the documents that make up "The Law of the River."

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The Painted River

The Colorado was so named by Spanish explorers because of its ruddy color. The force of the water against the steep gradient and the composition of the rock formations in the Colorado basin contribute to the river's excessive amount of erosion. The river carries more silt than most rivers, and has a high concentration of dissolved minerals in the water.

The river carries nine million tons of salt annually. The Colorado flowing into the Imperial Dam contains about 2,000 pounds of salts per acre-foot compared with the 300 pounds per acre-foot in the Sacramento River at Sacramento. Salinity increases downstream through the leaching of salts from saline soils and geologic formations due to natural processes as well as to agricultural and other activities of man, and the loss of water through evaporation, municipal, industrial and agricultural use, and through out-of-Basin exports. Minerals increase concentration because they are carried in less water. Extreme salinity can damage soil and crops and can corrode pumps, household plumbing and machinery. Highly saline water is not suitable for municipal water supply or industrial and agricultural uses without treatment to remove minerals. In the agriculturally rich area of the Imperial Valley one ton per acre-foot accumulates each year. Salt damage could double by the year 2020, say agricultural experts, with an annual loss to California farmers of more than $250 million. The increasing salinity is a serious problem on the lower Colorado. In 1973, the United States made an agreement with Mexico to improve the quality of water that was delivered to Mexico.

Also in 1973, the seven basin states formed the Colorado River Basin Salinity Control Forum. This group adopted a program for establishing water quality standards for salinity under Environmental Protection Agency (EPA) regulations. The Forum has conducted studies on salinity and recommended numeric criteria and a salinity control plan to meet the criteria. The criteria and plan have been adopted by the seven basin states and approved by the EPA. Several salinity control projects have been approved for the Colorado to meet the adopted criteria. To meet the agreement with Mexico, a large desalination plant near Yuma is scheduled for completion in 1993 at a cost currently expected to be $484 million. This Bureau of Reclamation plant will produce 73 million gallons a day of reclaimed irrigation water. With most of the salt removed, the water will be blended back to the Colorado flowing to Mexico at a salinity level low enough for Mexican farmers to use again. None of the water will be used in the United States but will fulfill our treaty obligation with Mexico. Critics say retiring nearby land from irrigation by buying out some local farmers would have been cheaper than constructing the desalination plant.

Indian Rights

The 1908 *Winters v. United States* Supreme Court decision that Indian rights existed whether or not water was actually being used by them was reaffirmed in the 1963 Supreme Court *Arizona v. California* decision. In the *Arizona* decision the Justices held that the five lower river reservations near the main stream of the Colorado River "were not limited to land, but included water as well . . . It is impossible to believe that when Congress created the great Colorado River Indian Reservation and when the Executive Department of this Nation created the other reservations they were unaware that most of the lands were of the desert kind—hot, scorching sands—and that water from the river would be essential to the life of the Indian people and to the animals they hunted and the crops they raised." The Court said the only feasible and fair way by which reserved water for the reservations can be measured is irrigable acreage, although Indians were not restricted to the use of the water for agriculture.

Today more than 20 years after the *Arizona* decision, Indians in these areas are only farming about 60 percent of their irrigable acreage. For a number of reasons including Indian poverty and concern by non-Indians that Indian projects will divert more water, the Indians have not financed expensive irrigation projects and have not received financial assistance from Congress. After the *Arizona* decision, in which the Indian Reservations were awarded over 900,000 acre-feet of diversion rights, the Indians made additional claims. In 1979 the U.S. Supreme Court turned those claims over to a Special Master. In 1982 the Special Master recommended that the Court uphold Indian claims that would permit them to receive some 1.2 million acre-feet or about one-third more water than already awarded by the *Arizona v. California* court. However, in a 1983 decision, the Supreme Court rejected the recommendation of the Special Master, ruling that some of the claims were made too late and that others required further resolution of boundary disputes before any more water rights could be awarded to the Indians. Litigation continues over the boundary disputes and in 1989 the Supreme Court appointed a Special Master to make recommendations to the court.

Water Management

California has been innovative in adopting programs to encourage more efficient use of Colorado River water. Lining of 49 miles of the Coachella Canal was completed in 1980. In 1988, the President signed legislation authorizing the Secretary of the Interior to line 28 miles of the All-American Canal and 38 additional miles of the Coachella Canal. One or more of the California agencies with contracts for delivery of Colorado River water would fund these projects to line the canals which are owned by the Federal Government. In turn, the 100,000 acre-feet of water saved annually by the projects would be available for use by the California agencies. Construction could begin in the early 1990s following completion of environmental impact statements. In the meantime, the U.S. Bureau of Reclamation, Coachella Valley Water District, and the Metropolitan Water District of Southern California (MWD) are sponsoring a demonstration of technology to line 1.5 miles of the Coachella Canal in place while water is flowing through the canal. The process involves shaping the canal prism and applying a geotextile polyvinylchloride liner and concrete cover. The demonstration project will allow for refinement of cost estimates, evaluation of environmental impacts, and verification of equipment operation.

Also in 1988, MWD and the Imperial Irrigation District signed a landmark water conservation agreement whereby MWD will contribute funds to implement 18 water conservation projects in the Imperial Valley over a 5-year period. Following their implementation, MWD will pay their operation and maintenance costs for a 35-year period. The projects consist of structural and non-structural conservation measures, including lining of existing irrigation canals, construction of local reservoirs and spill interceptor canals, installation of gates and automation equipment, and expansion of water management practices. The 100,000 acre-feet of water saved annually would be available to MWD during the period of the agreement.

Other proposals which may come to fruition in the 1990s include a ground water storage program on the East Mesa of Imperial County. Surplus Colorado River water might be recharged in the abandoned unlined Coachella Canal on the East Mesa for later use by the California agencies when their water supplies are short. Cooperative water utilization programs are also being considered. In years of water shortages, irrigation districts might make water available for urban use. To do so, lands in the districts would be removed from agricultural production, freeing the water that would otherwise be used on the farms. Landowners would be financially compensated for the revenue they forego by MWD.

Power

The Colorado River Basin plays a significant role in the economics of the western states because it is richly endowed with a variety of energy resources including water, coal, oil, gas, and uranium. Massive coal beds are widespread over much of the upper basin. In the Green River Basin of that area, one of the largest oil shale deposits in the nation is situated. With the vast resources, fossil fuels and hydroelectric power generation projects have been developed in the basin states.

The largest power generating plant is located at Hoover Dam. The Boulder Canyon Project (Hoover Dam) was constructed for the purposes of controlling the floods, improving navigation, regulating the flow of the Colorado River, providing for storage and for the delivery of the stored water thereof for reclamation of public lands and other beneficial uses exclusively within the United States, and for the generation of electrical energy. The main features of the project include the dam and reservoir, hydroelectric plant and high voltage switchyards. Electrical energy is delivered to the allottees at the high voltage switchyards and transmitted from that point to loads in Arizona, California, and Nevada over transmission facilities which are owned or arranged for by the allottees of electrical energy. In 1987 the Federal Government's 50-year contracts to sell Hoover Dam's hydroelectric power to utilities expired and new contracts were developed for using Hoover energy. Approximately 1,500 megawatts of inexpensive electricity is allocated to contractors. Metropolitan Water District of Southern California (MWD) now receives 17 percent, city of Los Angeles 34 percent, Southern California Edison Company 19 percent, Arizona Power Authority 13 percent, and more than 3 percent goes to municipalities.

Hoover power plant uprating, funded from non-federal resources, is presently under way to increase the capacity of the existing generator units. Upon completion in 1992, Hoover power generation will increase to an anticipated output exceeding 2,000 megawatts. Power is also generated at Parker Dam and Davis Dam. The Colorado River Storage Project also provides significant power.

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Unresolved issues

Although agreements have established the basic water entitlements among the basin states and with Mexico, the controversy over the Colorado is far from ended. The dilemma is whether there will be enough water in the Colorado to meet the entitlements and to supply the projects that are authorized but not yet built.

When the Colorado River Compact was negotiated, the Reclamation Service estimated the annual average runoff at Lee's Ferry to be more than 18 million acre-feet. It appears today that the figure is closer to 14 million acre-feet annually.

The Colorado basin has pioneered many changes in water management. The Colorado River Compact marked the first time that more than two or three states negotiated a treaty to settle their differences. The Colorado was also the first drainage basin where the multiple use of water was planned. Major projects on the Colorado were planned for municipal and industrial water supply, power development, irrigation, flood control and recreation.

The Colorado River below Parker Dam

Though nearly one million acre-feet of rights to Colorado River water have already been awarded to the Indians, the total rights of all Indian tribes to Colorado River water is still very much in doubt. The *Arizona v. California* Supreme Court decision in 1963 awarding water rights to five Indian reservations in the lower basin has implications that may greatly increase the rights of other Indians to Colorado River water. Many Indian water rights are now being used. If these rights are exercised, there could be even greater shortages than those that can be expected because of the optimistic apportionments under the Compact.

Water quality problems in the Colorado are equally serious, and will become even more severe as the basin states use their share of the Colorado River. The basin states are working cooperatively with the federal government and with each other to resolve these problems.

Various measures are being examined to supplement the flow of the Colorado. The possibilities include desalting of sea water and weather modification by cloud seeding and vegetation management to reduce evaportranspiration losses and increase stream flow. Another major unresolved issue is the development of oil shale in the upper basin states, which is potentially a very large water use.

The competition for water will continue and, with it, the inevitable animosity that causes a Colorado delegate at a water conference to categorize a California delegate as a "lower basin person." Yet regional planning is much more acceptable today than it was to the independent-minded Western people of the nineteenth century, and significant progress has been made by cooperating to preserve and protect our resources. The problems will not be solved easily, but with a spirit of cooperation and with new technology, they can be solved.

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ayperson's Guide to he Delta

Prepared by the Water Education Foundation

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1990

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For information on the Foundation's other information and education programs contact:

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On the Cover

This photograph of Georgiana Slough is from *Delta Country*, written by Richard Dillon and photographed by Steve Simmons. The book gives an historical overview of this timeless land, from the days of the Indians and early explorers to settlement and development of today's agribusiness. The uncertain future of this unique area is also considered.

Introduction

Flowing south, fed by northern Sierra Nevada runoff, the Sacramento River meets the northbound San Joaquin River to form the Sacramento-San Joaquin Delta in the Central Valley. The two rivers mingle with smaller rivers to form a 700-mile maze of rivers and sloughs surrounding 57 islands, most of them now agricultural.

Their combined freshwater flows then roll on through the Carquinez Strait, a narrow break in the Coast Range, and on into San Francisco Bay's northern arm. Suisun Marsh and adjoining bays are the brackish transition between the fresh water flowing from the rivers and the salt water of the Bay.

The area has always been at the mercy of river flows and tides. Before humans changed the Delta environment, salty ocean water from San Francisco Bay crept up Delta channels during dry summers; when mountain runoff ebbed. Then, during the winter, heavy runoff from the mountains kept the sea water at bay. The early diaries of Spanish explorers indicate that the salt line moved according to the relative dryness of the year. A great flood in the 1860s resulted in a substantially freshwater Bay. Conversely, salt water reached as far as Sacramento in the 1930s. Today, upstream dams including Oroville and giant Shasta help control saltwater intrusion by releasing water into the Delta system during dry times.

The Delta, as we know it, is largely a human invention. Early explorers found a vast mosquito-infested tidal marshland covered with bullrushes called tules. Later, trappers took advantage of the abundant wildlife. They were followed by farmers, some of them unsuccessful gold-seekers, who discovered in the Delta wealth of another sort: fertile soil. Over a century ago, these farmers, using Chinese laborers, began building a network of levees to drain and "reclaim" this fertile soil. Progressively higher levees were built to keep the surrounding waters out, lands were pumped dry, and what once was uncontrolled marshland was transformed into productive farmland. By 1930 more than 1,000 miles of levees surrounded close to 500,000 acres of farmland.

No other single area is quite as crucial to the state's overall water picture as the Delta—it forms the cornerstone of California's two largest projects: the State Water Project (SWP) and federal Central Valley Project (CVP). Its existing channels are used to transport water to the federal and state pumps both in the western and southwestern Delta. From the Delta, water is channeled south and west through canals and aqueducts to the north and south Bay areas, Contra Costa County, agriculture-rich San Joaquin Valley and to over 16 million urban Californians, mostly in southern California.

Water that would otherwise flow into the Delta is also diverted upstream by local users and some exporters such as the East Bay Municipal Utility District on the Mokelumne River and San Francisco's Hetch Hetchy project on the Tuolumne River.

Water also flows west through the Delta and San Francisco Bay to the ocean, partially holding back the salt waters of the Bay and protecting water quality for urban uses, recreation, fish and wildlife and Delta agriculture. With brackish marshes and San Francisco Bay next door, the Delta forms part of an estuary and an important habitat for millions of migrating wildfowl, fish and other fauna and flora.

Yet above the picturesque waters of the estuary a decades-long tempest over the distribution of its waters has brewed. Comprising just one percent of California's total area, the Delta is at the heart of both the state's water supply system and water controversies, providing almost 55 percent of the state's water supply, including 40 percent of its drinking water.

Water issues have always been of crucial concern not only in California but the entire western United States, a region which depends very heavily on developed surface supplies of water. But even with long-standing awareness and concern, water remains one of the least understood of all our natural resources.

Through the following pages, the *Water Education Foundation* has attempted to present an accurate and balanced discussion of one of the most fought-over areas in this state, the Sacramento-San Joaquin Delta.

Many technical reports, scientific studies and political analyses have been prepared on the Delta. But for us, the laypeople, a simple and more basic explanation of this complex subject is helpful. This *Layperson's Guide* attempts to meet that need and in so doing describes the important relationships between the Delta and the state's overall water picture.

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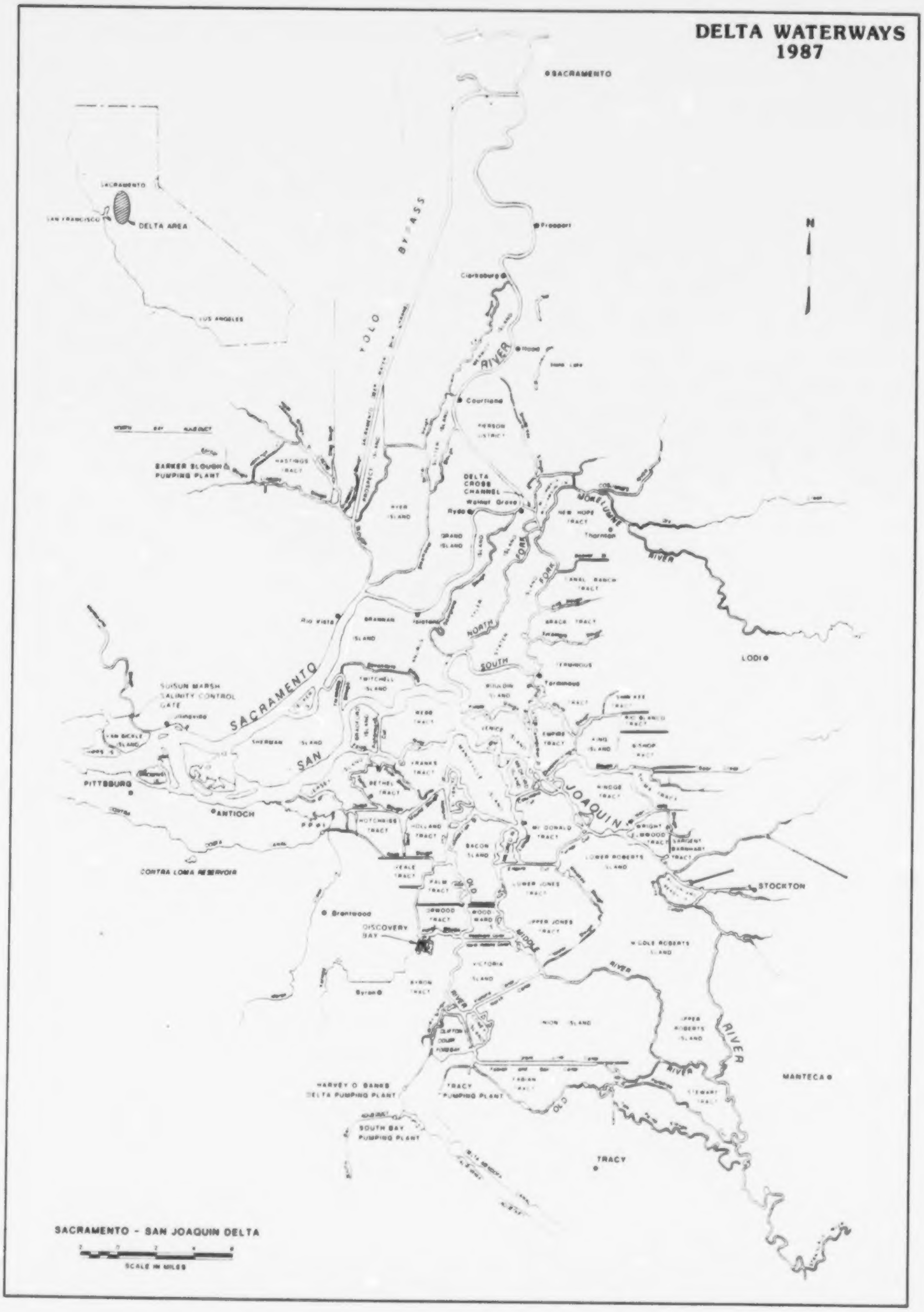
DELTA WATERWAYS
1987
SACRAMENTO
SAN FRANCISCO
DELTA AREA
LOS ANGELES
Freeport
Clarksburg
Hood
YOLO
BYPASS
RIVER
Courtland
PIERSON DISTRICT
BARKER SLOUGH PUMPING PLANT
HASTINGS TRACT
RYER ISLAND
DELTA CROSS CHANNEL
Walnut Grove
Ryde
GRAND ISLAND
NEW HOPE TRACT
Thornton
MOKELUMNE
RIVER
NORTH
FORK
SOUTH
FORK
CANAL RANCH TRACT
BRACK TRACT
TERMINOUS
Terminous
Rio Vista
BRANNAN ISLAND
Isleton
LODI
SUISUN MARSH SALINITY CONTROL GATE
Collinsville
SACRAMENTO
TWITCHELL ISLAND
SHERMAN ISLAND
VAN SICKLE ISLAND
BOULDIN ISLAND
VENICE
EMPIRE TRACT
KING ISLAND
BISHOP TRACT
BRADFORD ISLAND
WEBB TRACT
FRANKS TRACT
BETHEL TRACT
SAN
JOAQUIN
PITTSBURG
ANTIOCH
HOTCHKISS TRACT
HOLLAND TRACT
McDONALD TRACT
RINDGE TRACT
WRIGHT ELMWOOD TRACT
SARGENT BARNHART TRACT
BACON ISLAND
LOWER ROBERTS ISLAND
CONTRA LOMA RESERVOIR
VEALE TRACT
PALM TRACT
LOWER JONES TRACT
STOCKTON
Brentwood
ORWOOD TRACT
WOODWARD
UPPER JONES TRACT
DISCOVERY BAY
MIDDLE
MIDDLE ROBERTS ISLAND
VICTORIA ISLAND
Byron
BYRON TRACT
UNION ISLAND
UPPER ROBERTS ISLAND
CLIFTON COURT FOREBAY
HARVEY O. BANKS DELTA PUMPING PLANT
TRACY PUMPING PLANT
FABIAN TRACT
OLD
RIVER
STEWART TRACT
MANTECA
SOUTH BAY PUMPING PLANT
TRACY
N
SACRAMENTO - SAN JOAQUIN DELTA
SCALE IN MILES

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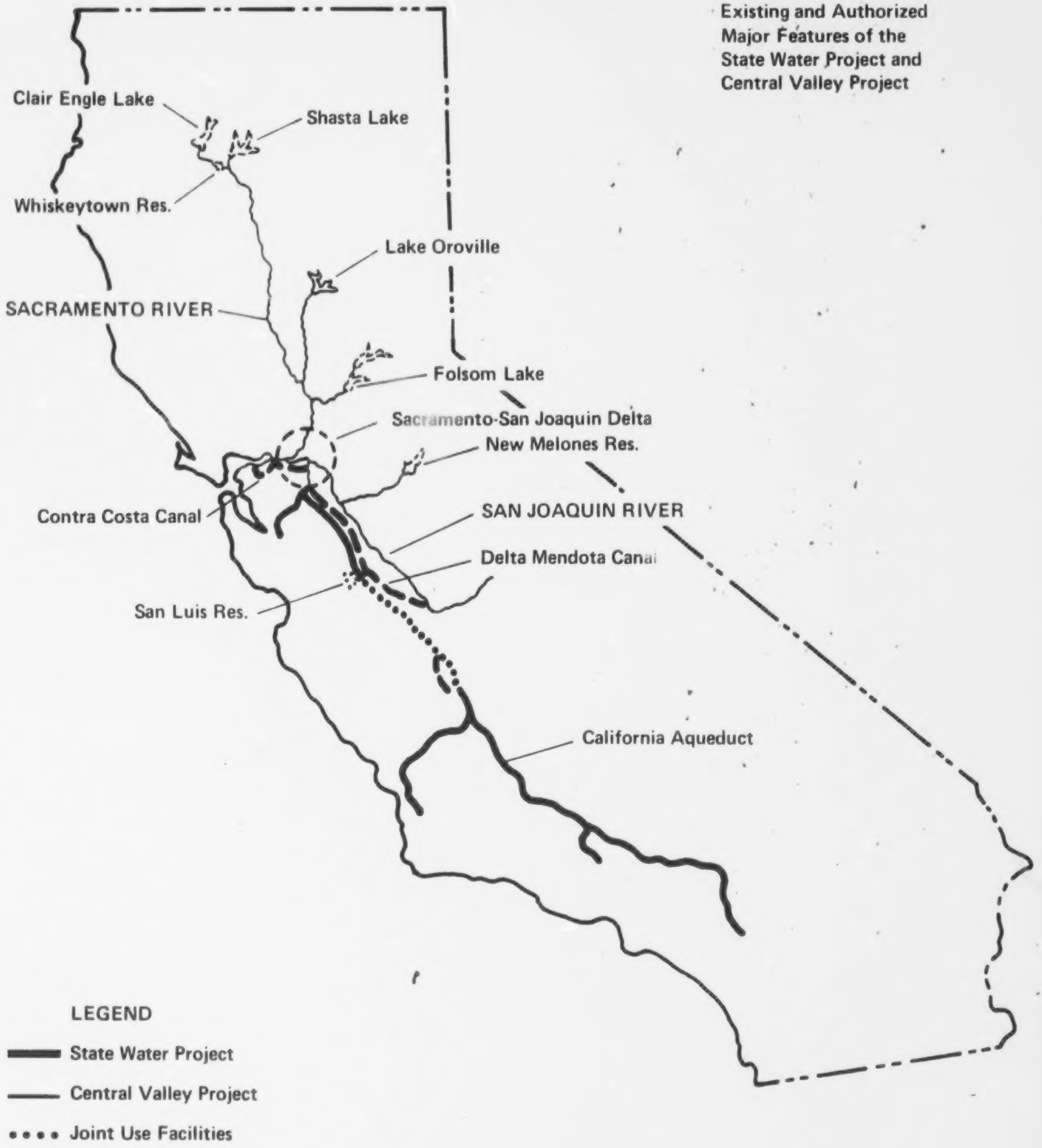
4

Existing and Authorized Major Features of the State Water Project and Central Valley Project


Clair Engle Lake
Shasta Lake
Whiskeytown Res.
Lake Oroville
SACRAMENTO RIVER
Folsom Lake
Sacramento-San Joaquin Delta
New Melones Res.
Contra Costa Canal
SAN JOAQUIN RIVER
Delta Mendota Canal
San Luis Res.
California Aqueduct
LEGEND
━ State Water Project
— Central Valley Project
• • • • Joint Use Facilities

Chronology

1772	First recorded sighting of the Delta by Fray Juan Crespi and Captain Pedro Farges
1849	Settlers begin arriving in the Delta region to farm its rich land, one year after the discovery of gold in California
1861	California Legislature authorizes the Reclamation District Act allowing drainage of Delta lands and construction of sturdier levees to protect the area from flooding
1914	Passage of the Water Commission Act
1930	Completion of a comprehensive State Water Plan calling for major transfers of northern California water to Central Valley
1940	Contra Costa Canal, the first unit of the federal Central Valley Project (CVP), is completed and use of Delta channels to convey water for export begins
1944	Completion of Shasta Dam and reservoir as the key feature of the CVP, adding water to Delta channels during naturally low-flow periods
1951	The State Feather River Project (now State Water Project) authorized by the California Diversions from the Delta begin for the CVP's Delta-Mendota Canal
1959	State Delta Protection Act approved by the state Legislature
1960	California voters approve the Burns-Porter Act to assist in financing the State Water Project, including Delta facilities for water conservation, water supply in the Delta, transfer of water across the Delta, flood and salinity control and related functions
1961	State Department of Water Resources (DWR) initiates the Interagency Delta Committee, consisting of DWR, U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers, to find solutions to Delta problems
1965	Interagency Delta Committee releases its report which contains a variety of proposals designed to offset adverse effects of increasing use of water from the Delta. The proposal included a plan for a Peripheral Canal Department of Water Resources officially selects the Peripheral Canal as the Delta water facility of the State Water Project
1967	Construction begins on SWP's Clifton Court Forebay Initial diversions begin from the Delta to the California and South Bay aqueducts of the state water project
1969	U.S. Department of Interior adopts the Bureau's Peripheral Canal Feasibility Report and recommends the project be a joint-use facility of the CVP and SWP with shared costs
1970	State endorses a joint-use facility, urges Congressional authorization on the condition that Delta water requirements have priority over exports
1971	State Water Resources Control Board adopts its Delta Water Rights Decision 1379 establishing water quality standards to be met by both CVP and SWP
1972	DWR announces that the state is proceeding with planning of the Peripheral Canal as a state-only project First SWP deliveries to southern California
1973	Delta Environmental Advisory Committee forms. As part of a three-point solution, the committee concludes in January 1977 that a properly designed, built and operated facility such as the Peripheral Canal is necessary Department of Fish and Game concludes a 10-year study which probes the Delta's problems. Report concludes a Peripheral Canal is the most desirable plan for a Delta water facilitiy
1974	DWR, state Department of Fish and Game, the Bureau of Reclamation and U.S. Fish and Wildlife Service sign a statement of intent that the agencies will provide protection of fish and wildlife resources in the Delta
1975	DWR calls for complete reappraisal of alternative possibilities for Delta water management problems U.S. Department of Interior releases its opinion that the Federal Water Pollution Control Act does not require the Bureau to release water for salinity repulsion in the Delta DWR releases a legal opinion stating the Federal Water Pollution Control Act does apply to the operation of the CVP
1977	After reviewing nearly 40 alternative courses of action in the Delta, DWR reaffirms that building the Peripheral Canal is the best answer to Delta problems
1978	State Water Resources Control Board issues SWP-CVP Water Rights Decision 1485 regarding CVP and SWP operation to provide water quality control in the Delta
1979	Secretary of the Interior Cecil D. Andrus announces the CVP will be operated to voluntarily meet state Delta Water quality standards (Decision 1485) until legal questions of mandatory federal compliance are resolved. Negotiations between the state DWR and the federal Bureau of Reclamation Senator Ruben Ayala introduces Senate Bill 200 specifying the Peripheral Canal as the Delta transfer facility, not requiring federal participation
1980	Voters pass Proposition 8 insuring more Delta protections unless SB 200 is defeated
1982	Voters defeat Proposition 9, which includes the Peripheral Canal SB 200 package, by 3-2 margin. Northern Californians vote 9-1 against SB 200 and Southern Californians vote 3-2 for the bill
1983	DWR releases a report analyzing four through-Delta alternatives to the Peripheral Canal
1984	Attention focuses on Governor Deukmejian's through-Delta plan utilizing natural Delta channels and reconstructed levees. By June "Duke's Ditch" (SB 1369) is shelved
1986	Congress passes State DWR and U.S. Bureau of Reclamation historic accord, the Coordinated Operation Agreement (COA) California Supreme Court affirms state Court of Appeal ruling (Racanelli decision) strengthening powers of State Water Resources Control Board to protect all uses of Delta water, and potentially San Francisco Bay DWR and DFG sign Delta Pumping Plant fishery mitigation agreement for direct fish losses
1987	The State Water Resources Control Board begins the San Francisco Bay/Sacramento-San Joaquin Delta Estuary Hearing (Bay-Delta Proceedings)
1988	Senate Bill 34 provides $120 million over 10 years for DWR to rebuild levees, enlarge channels and to help reclamation districts make levee improvements Suisun Marsh facilities (tide gates) begin operation to provide water quality for waterfowl protection Construction begins on four additional pumping units at the Delta Pumping Plant
1988	An engineering study by the California Urban Water Agencies examines options for improving drinking water quality for users of Delta water
1993	Expected completion of State Water Resources Control Board's new Water Quality Control and Water Right decision

Background

California is a land of great diversity. Within its boundaries lie vast mountain ranges, sprawling deserts, miles of picturesque coastlines and major urban areas. This state is the world's leading agricultural producer and simultaneously is home to more than 28 million residents, making it the most populous state in the nation.

No other single resource has been more important to the development of California than its water. California's natural water picture is also a study in contrasts. Two-thirds of the state's water originates north of Sacramento, while 70 percent of its users live south of the Capitol City. Most of the state's rainfall occurs in winter and spring while peak demand occurs in the hot summer months. This is the setting for California's water story. As *Time* magazine once noted, "California has everything - usually in the wrong place."

Adjusting water distribution in time and place is at the heart of California's water development program. Winter and spring flows are stored in reservoirs for use during the summer growing season, and the excess runoff of wet years is captured for use during drought periods. Large amounts of runoff are stored in ground water basins which serve as a mechanism for balancing irregularities in water supply.

To regulate the distribution of water, major water storage and transportation facilities have been built in California. The Delta is at the heart of the two major projects in California, the State Water Project (SWP) and the federal Central Valley Project (CVP).

The Sacramento-San Joaquin Delta lies at the center of almost all discussions of California's future water supply. What could possibly be so important about the Delta? Why should such a small area, 700,000 acres in total, be embroiled in such controversy and have such an effect on the state's future?

The Delta lies in that area where the Sacramento and San Joaquin Rivers converge to discharge over 40 percent of the state's total runoff into San Francisco Bay. In addition, it is the low point of the Sacramento-San Joaquin Valley through which water flows before going to the ocean. Consequently, whatever affects the Delta affects large portions of northern, central and southern California.

Problems, whether environmental, political or engineering in nature, are nothing new to the Delta region. Since the first settlers arrived in the area, the Delta has simultaneously offered a fertile, rich environment and seemingly insurmountable problems.

Legend has it that the first explorers to set eyes on the vast tidal marshland now known as the Sacramento-San Joaquin Delta were two soldiers from the party of the explorer Hernando Cortez in 1520. Mosquito-infested and tule-covered, the Delta was a rare sight to these early day conquistadors.

In 1771, Pedro Farges first recorded sighting the Delta. In 1776, Juan Bautista de Anza gazed upon the immense expanse of waterways and tules from the foothills overlooking the Carquinez Strait.

Farges and de Anza were the first to provide written accounts of the abundance of wildlife in the Delta region. Later, in 1827, American adventurer Jedediah Smith provided detailed accounts of trapping and hunting in the area. Smith trapped beaver, otter and mink on the periphery of the giant marsh and blazed a trail north to Fort Vancouver, where his tales of the wealth of animal pelts yielded by the Delta were heard with keen interest by the Hudson Bay Company.

During the next 15 years, trappers were a familiar sight in the Delta. Seagoing ships navigated the Sacramento and San Joaquin rivers to bring in supplies and to take out tallow and an ever increasing number of animal skins.

Growth during this time was characterized as steady and slow, but in 1848 the trend changed. Gold was discovered in the Sierra Nevada foothills, and the stampede to California was on. When the gold ran thin many of these newcomers turned to one of California's richest resources - its fertile soil. They settled in large numbers throughout the Sacramento-San Joaquin Valley region.

But farming in the Delta wasn't without serious perils. The land was constantly threatened by flooding. Farmers and Chinese laborers began building series of small levees - called shoestring levees - to hold back flood water. Their efforts were mostly futile, as the levees were able to hold back little more than a high tide.

During the second half of the 19th century, great strides were taken to convert the marshlands of the Delta into primarily an agricultural area. New techniques were tried as part of these reclamation efforts. Mechanical power was applied to dredging, levee building, ditching and land clearing. Pumps were introduced in 1876 to control water levels on reclaimed land. Levee-building projects ultimately turned what was once an uncontrolled marshland into productive farmland.

By 1880, the amount of reclaimed area rose to 100,000 acres; by 1900, it had reached 250,000 acres. And during the next 30 years, the amount of reclaimed land grew to almost 450,000 acres, all of this accomplished by local interests.

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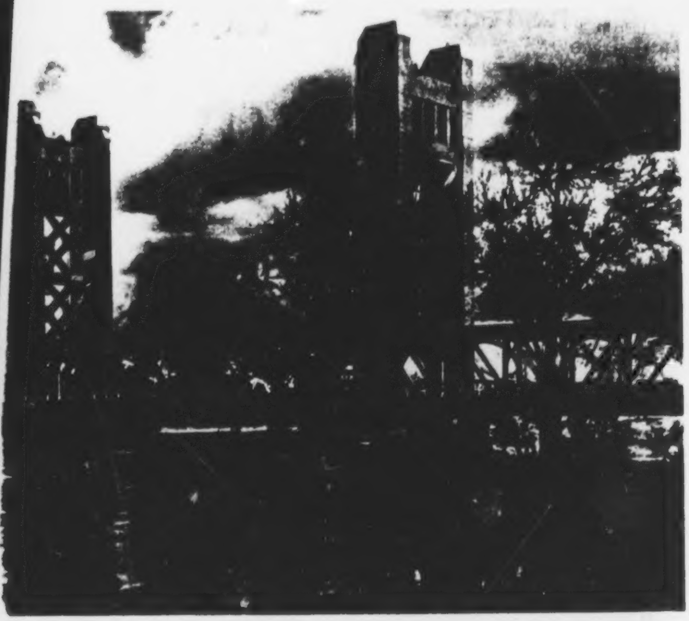

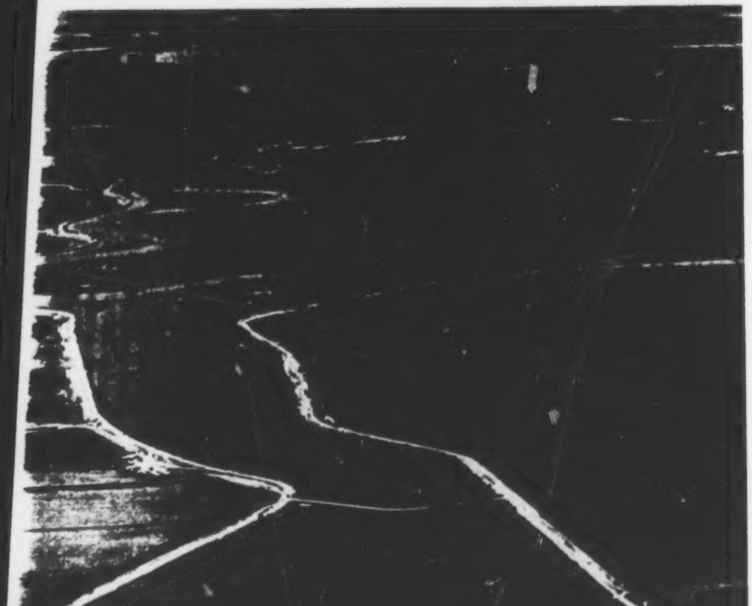

At the same time successful farming was burgeoning in the Delta, new species of fish and game were introduced into the area. Striped bass, American shad and white catfish were brought to the Delta. Game birds, imported varieties of orchard and field crops and new breeds of livestock also were introduced.

Ironically, though, man's attempts to harness the natural resources of California were causing problems of equal significance to his accomplishments. Starting in the 1860s, the Delta suffered enormous damage from the vast amounts of sediment and debris swept downstream from hydraulic mining in the mountains far up the Sacramento and San Joaquin rivers. Even after an 1884 federal court injunction halted these mining operations, silt continued to settle in the Delta, altering the navigable channels and greatly hindering shipping activity.

Deposited silt also reduces the Delta channels' carrying capacity, increasing the dangers of flooding when the rivers rise. Over the years, these channels were dredged to improve navigability and reduce flooding. (Today, silt deposits, sometimes accelerated by human activities, are still a problem.) By the turn of the century, because of low Delta outflows in dry years, saltwater intrusion into the Delta from the ocean became an increasing problem. In contrast, high water levels during the winter season and occasional high tides caused many of the Delta islands to flood.

High flood waters on the Sacramento River also caused problems, and in 1880 the State Engineer devised an integrated flood control plan which eventually came to include a system of levees and bypasses transporting floodwaters past protected areas. After a series of flood years in the Sacramento Valley, Congressional authority for the Sacramento Flood Control Project by the U.S. Army Corps of Engineers was finally granted in 1917, and the project was completed in 1960.

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In 1921, the state legislature authorized an extensive investigation by the State Engineer to develop a comprehensive water plan for California. For the next 15 years, federal, state and local interests wrangled over how to best supply California with a dependable source of water and reduce salinity intrusion into the Delta. The state Central Valley Project Act, passed and approved by voters in 1933, authorized building reservoirs to supply water and provide a hydraulic barrier to repel seawater intrusion, but could not be financed by the state during the depression. In 1937, the Department of the Interior was authorized by the Rivers and Harbors Act to construct a federal Central Valley Project.

The use of the Delta channels as conduits for transporting water began in 1940 with completion of the Contra Costa Canal, the first unit of the CVP. With the completion in 1951 of the Delta-Mendota Canal—part of the CVP, which begins at Trinity Dam and ends in the lower San Joaquin Valley—the Delta became part of a vast water export system. Also in 1951, the Delta Cross Channel was constructed near Walnut Grove in the North Delta to facilitate favorable flow patterns for water transfer across the Delta by the CVP.

Also in 1951, the state authorized the Feather River Project and Delta Diversions Projects, later known as the State Water Project (SWP), and in 1960 the Burns-Porter Act defined and funded the facilities of the SWP.

In 1967, the state also began pumping water from the Delta into its California Aqueduct, part of the SWP which today serves the north and south Bay area and the San Joaquin Valley, as well as much of the densely populated Southland.

By 1975, the combined deliveries of the SWP and CVP, both north and south of the Delta, had grown to about 4.8 million acre-feet; by 1988, the total reached around 10.6 million acre-feet. Prior to the CVP and SWP, many of the state's ground water basins were overdrafted; the projects helped alleviate this problem by substituting surface water for ground water mining.

The Delta Today

By definition, an estuary is an interconnected area where tidal and river currents meet, and where salinity (saltiness) is between the extremes of ocean and fresh waters. The Delta, Suisun Bay, San Pablo Bay and south and central San Francisco Bay form such an estuary.

The estuary is hydrologically complex. The Sacramento and San Joaquin rivers are the major source of freshwater inflow to the estuary, with the Sacramento River the largest contributor. The area where river flows and tidal flows interact most intensively, known as the "entrapment zone," is of ecological significance to many plants and animals residing in or migrating through the estuary. The location of the entrapment zone moves back and forth from the Delta to near San Pablo Bay depending on Delta outflow and the ocean tides.

Downstream of Suisun Bay, the estuary is more subject to daily tidal forces, although moderate to high seasonal freshwater flows and prevailing wind patterns still affect circulation patterns.

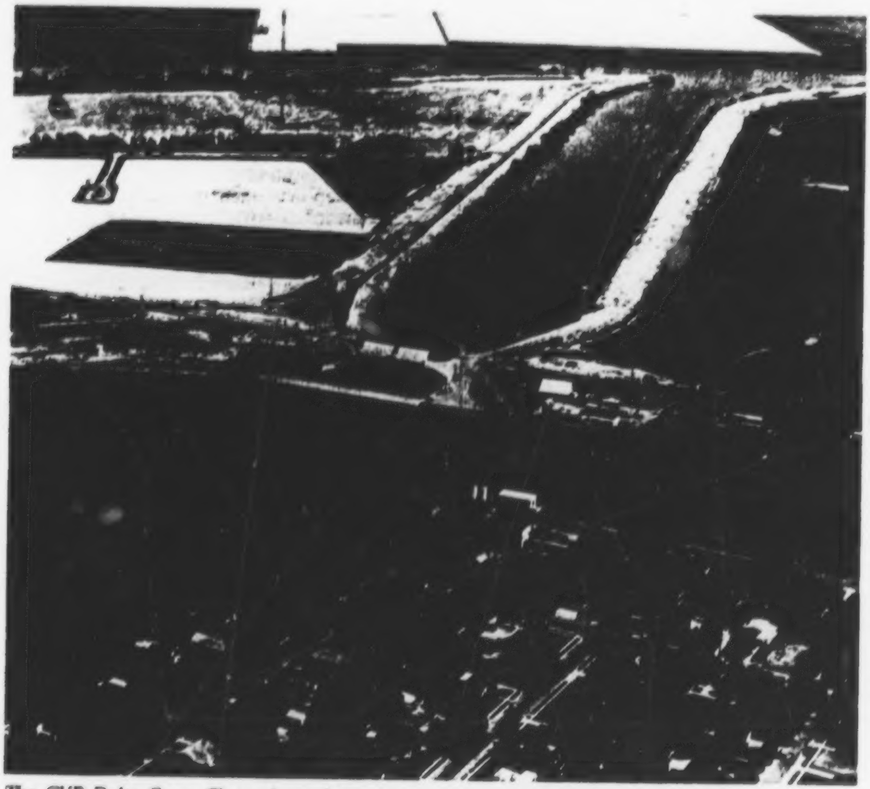
The estuary is constantly changing. For instance, according to the Bay Conservation and Development Commission, San Francisco Bay has shrunk since 1850 from 780 to 550 square miles due to the construction of dikes and the filling of low-lying areas. Also, the South Bay was plagued with fish kills and algal blooms in years prior to the passage of the federal Clean Water Act in 1972. Since the passage of the act, investments in the treatment and disposal of municipal sewage have greatly reduced these problems.

Today, the estuary is connected not only ecologically, but also through the various uses made of it. The Delta contains numerous below-sea-level islands protected by levees. The surrounding levees and channels, and the islands themselves, serve as passageways for migrating fish and provide valuable habitat for a wide variety of fish and wildlife. The leveed islands are also productive agricultural lands, generating an average gross crop value of $375 million, according to the Department of Water Resources (DWR) *Sacramento-San Joaquin Delta Atlas*.

The Delta also supports over 8.5 million user-days of recreation annually, from boating and waterskiing to sport fishing, which contribute to the area's economy.

Perhaps one of the biggest obstacles to resolution of the Delta's myriad problems is the enormous complexity of the issues and the way in which each fits tightly with the other. Each of the Delta's problems, be it preserving the fisheries, maintaining water quality levels, managing Delta levees or making sure enough water is present for meeting agricultural and urban needs within the state, brings with it opposing points of view, special interest groups and new conflicts. For the most part, past studies and programs have taken a piecemeal approach to exploring and managing the Delta's—and the estuary's—problems. It is only recently that studies and programs, discussed later in this Guide, have begun to address the estuary as a whole rather than its component areas.

Delta Issues



The CVP Delta-Cross Channel regulates water passage in the Delta.

Water Distribution

The Delta, because of its geographical location, is the historical collection point for much of the runoff and resulting water supplies of California. And it is through Delta channels that this water must pass in order to satisfy the demands within the Delta itself, the agricultural lands of the San Joaquin Valley, the San Francisco Bay Area and the state's densely populated Southland.

Many who have studied the Delta believe that some of its environmental problems have been aggravated by the development of the state and federal water projects. The Bay-Delta region has played a key role in meeting the water supply needs of much of California's population. In the past, rapid growth and development were accommodated, to a large extent, by increased annual upstream and export diversions of some waters that would otherwise flow toward San Francisco Bay.

No one disagrees that there will be new demands for water in the state. By the year 2010, California's population is projected to rise from 28 to 36 million. Net water use throughout the state is expected to grow, too, by about 1.4 million acre-feet per year by 2010, according to DWR. Since the amount of water passing through the Delta for export is limited by the size of Delta channels, the SWP cannot maintain a reliable future water supply for the state without building an improved Delta water transfer system and constructing more storage, according to DWR.

Present and past state administrations believe development of additional water for the state project is crucial. But environmental groups and others oppose increased development of Delta water on the grounds that more diversions may further harm the estuary's ecosystem. Indeed, some groups argue for reduced Delta diversions to allow more fresh water to flow through the estuary, especially during the spring when some anadromous fish migrate upstream to spawn, and others migrate out to the ocean. They contend new demands can be met by more efficient use or reallocation of already developed supplies from agricultural to urban uses.

The "Tule Theory"

Although human modification of the Bay-Delta estuary began in the mid-1890's—relatively recently in the estuary's overall timespan—accurate measurements of the amounts of water flowing from the Delta through the Bay are only available beginning in the early-1900's.

Today there is interest in just how much water flowed through marshes in the early days because of testimony brought up in the State Water Resources Control Board's Bay-Delta Proceedings concerning historic freshwater flows. Many arguments in favor of requiring more freshwater inflow to the Bay cited estimates of as much as a 60 percent reduction in "historic" flows to the Bay due to increased land use and export diversions.

But testimony offered by consultants to the State Water Contractors (a group of 28 of the 30 agencies that buy water from the State Water Project) in the Proceedings stated that as much water actually reaches the Bay today because California has been experiencing an overall period of increasing precipitation. Also, they stated that in frontier times vast acres of tule marsh and riparian forest in Central Valley consumed much of the water that would have flowed into the Bay.

The "tule theory" pointed out that the estimates that water project diversions allow only a fraction of historic flows into the Bay had not included the amounts formerly consumed by Central Valley vegetation, much of which used more water per acre than any of the currently cultivated crops.

As the Bay-Delta Proceedings continue, there remains a question of how much fresh water actually flowed into the Bay and how much was absorbed and transpired through marshlands in the Delta and in the entire Central Valley. Nevertheless, the State Board is left with the amount of water that is available today and in the future to allocate to urban, agricultural and environmental needs.

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Because an estimated 80 percent of California's developed water is used by agriculture, some of it either used upstream or imported through the Delta, those with interests in this $14.5 billion annual industry are understandably concerned about the continued availability of Delta waters.

Water districts in Kern County, for instance, serve 1.5 million acres of California's most productive farmland, with an estimated crop value of $1.6 billion in 1986. Decreases in the amount of water to farming, the agricultural community argues, could damage the state's agricultural economy, with serious social and economic effects on many farming communities. Various proposals to increase the Delta's water transfer ability have been proposed over the years.

Salinity and Agricultural Drainage

Salinity, either intruding from the sea or accumulating as minerals from the state's agriculture and discharged into the Delta's tributaries, has long been a Delta issue.

Freshwater outflow repels the intrusion of sea water into the Delta, helps to provide necessary levels of nutrients for the estuary's many flora and fauna, and mixes with heavier salt water to create a dynamic circulation process that helps disperse pollutants and maintain adequate water quality. During dry years, or dry parts of the year—late summer and early fall—the state and federal reservoir projects help to control salinity by releasing water held in reservoirs. But after a prolonged drought, there often isn't enough water left for salinity repulsion. And during the spring when reservoirs are being filled, Delta salt concentrations can go up, creating salt intrusion problems for Delta farmers and municipal and industrial users.

Compared to other Delta areas, the western Delta suffers periodically from higher saltwater content and its possible adverse effect on drinking water supplies of more than one-third million residents of eastern Contra Costa County. The more fresh water flowing from the Delta to San Francisco Bay, the better the water quality in the western Delta.

Over the years, four basic types of facilities were studied to solve salinity intrusion and other problems in the Delta. They are: 1) hydraulic barriers—the provision of sufficient Delta outflow to repulse ocean salinity, basically the method used today and an integral part of the remaining types of facilities; 2) physical barriers—actual low-level dams separating fresh water from saline water with passageways for navigation and fish migration; 3) waterway control—alterations and facilities in existing channels to improve flow patterns; and 4) isolated channels—new channels to isolate export water from Delta waters and provide for releases to the Delta. Plans that were combinations of these concepts were also studied.

Water Right Decision 1485, issued in 1978 by the State Water Resources Control Board, sets salinity standards to protect the water supply for the Delta's broadly grouped beneficial uses: fish and wildlife, agricultural, municipal, industrial and recreational uses. The decision's underlying premise is that Delta water quality should be at least as good as the levels available had the state and federal projects not been constructed, with adjustments built in to accommodate changes in hydrologic conditions under different types of water years. A monitoring program is required to gauge compliance. Revisions of this decision are now under consideration; the "Bay Delta Proceedings" began in early 1987, and enactment is expected in 1992 or 1993. (See page 17. Bay-Delta Proceedings.)

Agricultural drainage also contributes to salinity problems in the Delta. Because most of the Delta islands are below sea level, the area is beset by seepage-related problems. Farmers must constantly pump water from their lands to permit crops to grow. However, farmers must also add controlled amounts of water for productive agriculture. In the South Delta farmers rely primarily on the waters of the San Joaquin River for their irrigation supply. The process of irrigation and leaching minerals from the soils concentrates salts in the drainage water which is then pumped into nearby Delta channels. Sometimes there is no current to "flush" these salts through the Delta, creating localized salinity problems.

The salt content of drainage water flowing down the San Joaquin River, primarily from the west side of the valley, is high and sources of dilution water are limited. Most of the valley gets an average of less than 10 inches of rainfall a year and water historically received from Sierra streams is now largely retained by dams and either exported or diverted for consumptive uses. Flows in some stretches of the San Joaquin River, during droughts and the summer irrigation season of dry years, consist almost entirely of irrigation return flows, including surface runoff and subsurface drainage from irrigated east-and west-side lands and, to a lesser extent, from public and private wildlife management areas.

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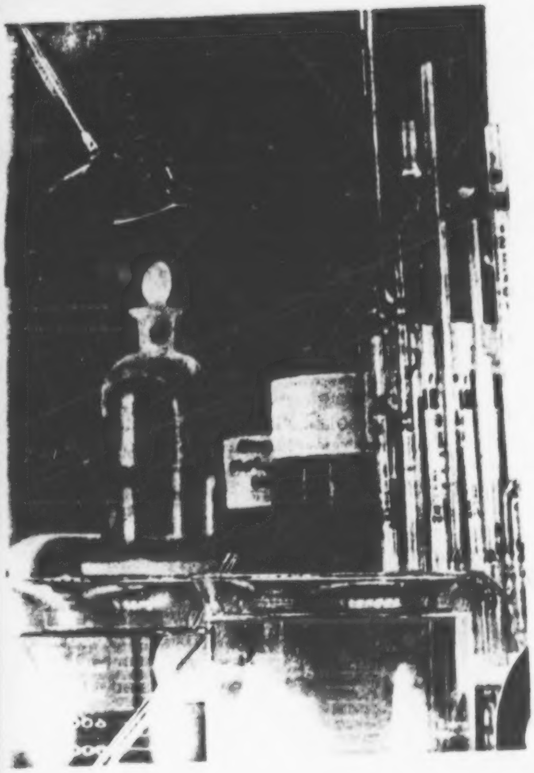

Drinking Water Quality

Drinking water quality is an issue of growing concern to domestic water users and water agencies which supply water from the Delta source. The elevated concentrations of salts and minerals continue to be of concern; however, much greater public attention is now focused on organic contamination from natural and synthetic organic chemicals and their reactions with chemicals used in the water treatment process.

Tastes and odors can also be a problem in treated water supplies from the Delta. Taste and odor are due mainly to organic compounds but are also occasionally due to high mineral content.

A clear indication of the increasing concern of California citizens about the quality of their drinking water is the growing use of bottled water and home treatment devices, even though the tap water meets all state and federal drinking water standards. The people who use Delta water are the highest bottled water users in the state.

When water from the Sierra rivers flows into and through the Delta, additional naturally-occurring organic materials (mainly derived from vegetation) are added to those already in the water as it contacts the Delta's peat soils. Organic material is also added by agricultural drainage from Delta farms. These organic compounds are precursors to the formation of disinfection by-products. The best known of these by-products are the trihalomethanes (THMs).

THMs formed upon chlorination of the precursor-rich Delta water supplies are of concern because THMs are an animal and suspected human carcinogen. This problem is exacerbated at certain times of the year when the powerful state and federal pumps in the south Delta draw water from the western Delta that includes ocean-derived bromides which produce other forms of THMs.

The THM problem could cost urban water purveyors billions of dollars over the years in additional treatment costs to meet anticipated higher EPA drinking water standards for THMs and other disinfection by-products.

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Increasing evidence of Delta drinking water quality problems created interest in studying ways to operate existing water systems diverting water from the Delta in ways that will minimize contamination. Research by water agencies has shown that only with the installation of advanced and expensive water treatment will Delta water be able to meet anticipated drinking water standards for THMs and other disinfection by-products.

Such concerns led the California Urban Water Agencies (CUWA), a coalition of the state's largest drinking water supply agencies, to commission a study of Delta drinking water quality. The study, completed in 1989, investigated both operational and physical means of improving the existing water supply systems in order to improve drinking water quality.

The results of this Delta drinking water study show that the urban water agencies will have to use costly treatment techniques to meet anticipated tougher drinking water standards. However, less treatment will be required for drinking water diverted upstream of the Delta because those areas are less developed and the upstream waters contain lower amounts of contaminants.

The CUWA study reported several alternatives that could help improve the quality of Delta-source drinking water and concluded that alternatives that would take water upstream of the Delta would provide higher quality drinking water and would reduce overall costs to urban water users. The study did not attempt to analyze the many environmental, institutional and other impacts of the alternatives it presented, and stressed that much more study and assessments of these factors are needed.

Fish and Wildlife

The fish and wildlife that call the Bay-Delta Estuary a permanent or temporary home come in all shapes and sizes, from ducks and cranes to salmon and sturgeon. Millions of traveling birds exit the "Pacific Flyway," a major north-south migration route, to fuel up and rest at the 55,000-acre Suisun Marsh and other brackish marshes and freshwater wetlands around the Bay and Delta.

Delta fisheries have had their problems. Striped bass, an introduced species, feed in the Bay and ocean directly beyond the Golden Gate, migrating to the fresh water of the Delta to spawn. Once responsible for a $7.5 million sportfishing industry, from the mid-1960s the adult striped bass population declined from about 3.5 million fish to about 1 million today. Also, because of mercury in excess of health standards, an advisory was issued to consumers on limiting their intake of striped bass.

Increased exposure to toxics, introduction of new species, changes in food supply, loss of habitat and water diversions are all implicated in the decline of the striped bass fishery, but there is debate as to whether water withdrawal has caused or exacerbated the problems.

According to the state Department of Fish and Game, more than three-quarters of the state's multimillion-dollar commercial salmon catch depends upon the habitats of the Bay, Delta and tributary rivers. And natural spawning chinook salmon populations, too, are declining, although hatchery production has kept their overall numbers relatively stable. In 1989, however, the Sacramento River's winter-run salmon population, one of four California sub-species, reached a low of 500, down from 117,000 in 1969, causing the state Fish and Game Commission to list the run as endangered.

Another major problem in the Delta is that of reverse flows, which occur at certain times of the year when export water on its way to pumps flows down the Sacramento River into the western Delta and then back upstream in the lower San Joaquin River. Reverse flow problems have been implicated in the decline of migrating salmon and young striped bass which are either sucked into the pumps and killed or thrown off their spawning pilgrimage by this change of flow pattern.

Many believe that the fluctuating entrapment zone, where fresh and salt waters mingle, is very important to the food chain of the region. This area of circulating currents provides a particularly good habitat for the tiny plankton upon which larger organisms feed. Although the location of the entrapment zone fluctuates under natural conditions, diverting water upstream and out of the Delta also alters the location of the meeting place of fresh and salt waters, and some contend this adversely affects, at the most fundamental level, the food supply of the Bay-Delta estuary.

The timing of the fresh water influx may be more important than the total annual amount, with late spring and early summer diversions reducing the outflow that would otherwise occur as the Sierra snowpack melts and runs off. According to fishery biologists, this "spring flow" cycle is needed for the creation of the conditions favorable to migration and spawning for fish such as striped bass and salmon.

Spring, however, is the harvest season for water. Once the need for flood control stops in the spring, water managers need to place as much of this "spring flow" water as possible in storage to use throughout California's long, dry summers.

As brought up in the Bay-Delta Proceedings, there is no consensus on either the problems of fish and wildlife within the estuary or the solutions to those problems. Some argue that until direct, cause-and-effect relationships for fishery declines are found, current standards should not be changed. Furthermore, they argue that physical measures—such as fish screens at the pumps, improved water transfer facilities and upstream habitat enhancement—and, in the short term, increased hatchery production, should be used to protect the fishery or to offset losses in preference to augmenting flows.

Others hold that the amount of water discharged into the estuarine system is correlated to fish catches and that adequate freshwater flow is necessary to maintain habitat for fish and wildlife. They see short-term solutions such as hatcheries and screens as temporary, and at best only partial solutions, secondary to the issue of getting more fresh water through the Delta and out the Golden Gate. One thing is certain: isolating the variable(s) responsible for, and solutions to, fishery declines remains a difficult challenge yet to be met.

Delta Levee Issues

A well-maintained levee system is needed to protect the supply of fresh water moving through the Delta, fish and wildlife living in the Delta, recreation on Delta waterways, roads on levees and island floors, and farmlands and towns in the Delta. When levees fail, water rushes into the lower-than-sea-level islands and salt water can be drawn up from further downstream.

According to DWR, the collapse of Delta levees would create widespread flooding because most of the Delta islands are below sea level and would fill with water. In a summer situation with low freshwater flows to counter the pressure of the sea water, salt water would intrude farther into the Delta and into water that is used by millions for their agricultural and drinking supplies.

Much of the soil used to reclaim the Delta is now destroying it. On two-thirds of Delta lands, the local soil, composed of organic matter from the original marshlands, sinks or erodes at the rate of about three inches per year.

Today, most of the Delta is below the surrounding water level and many islands are 25 feet or more below sea level. Continually higher levees are necessary to hold back Delta waters, but some levee foundations are made of the stringy peat soil that oxidizes and compacts, or blows away. This compaction, known as subsidence, is a critical problem because the process puts stress on levees and makes island flooding more probable.

A major aspect of flood control in the Sacramento-San Joaquin Delta and along the rivers is stability of its levees, many of which are vulnerable to failure in high water situations.

Responsibility for federal project levee maintenance travels through three levels. After the U.S. Army Corps of Engineers completes a Congressionally-approved levee construction project in the Central Valley, the legal responsibility for the project is transferred to the State Reclamation Board, which then turns levee maintenance over to DWR or local public agencies. Outside the Central Valley, other levees are transferred directly from the Corps to local flood control districts, cities or counties.

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About 65 percent of Delta levees are "nonproject" - they were constructed and are maintained by island landowners through local levee and reclamation districts, to varying and generally less stringent standards than those for project levees, according to DWR. Many are in very poor condition. A part of Senate Bill 34, the "Delta Flood Control Protection Act of 1988," will increase the financial assistance to reclamation and levee districts maintaining nonproject levees throughout the Delta, and provide funds for special flood control projects in the northern and western Delta.

DWR is considering several improvements to the Delta to help alleviate its flood problems, including dredging, levee setbacks, channel improvements, and land use changes which would also provide water quality, fishery, wildlife, and water supply benefits.

Senate Bill 34 provides $120 million over 10 years for DWR to rebuild levees, improve channels and help local reclamation districts improve and maintain levees.

Another potential danger to levee stability is a major northern California seismic event. If an earthquake caused the Sacramento-San Joaquin Delta's fragile levee system to collapse, millions of individuals from the San Francisco Bay area to southern California could be left without adequate drinking water.

The state Legislature has required, through AB 955, the Department of Water Resources to devise an emergency plan that would allow the CVP, SWP, East Bay Municipal Utility District (EBMUD) and Contra Costa Water District to "continue or quickly resume exporting or delivering usable water (from the Delta) in the event of the failure of one or more levees in the Delta."

The emergency response plan as outlined by DWR would entail stopping the SWP and CVP pumps in the south Delta, filling Clifton Court Forebay for a reserve, waiting for the Delta to stabilize, and increasing releases from Folsom, Shasta, and Oroville reservoirs to fill up the Delta with fresh rather than salt water. Once stabilized, work to patch up the levees and block salinity intrusion could begin.

But many argue that massive Delta levee failure could not be so easily repaired -that the Delta is essentially a "weak link" in the state's water transportation system. Studies done for EBMUD concluded that long reaches of Delta levees built over sand pockets could liquefy under severe seismic loads and cause failure. (Liquefaction occurs when the earth shakes and saturated sand start to flow like liquid. Quicksand is an example of liquefaction).

Researchers are continuing to look at the effects of an earthquake on the Delta.

D-1485 and The Delta Plan

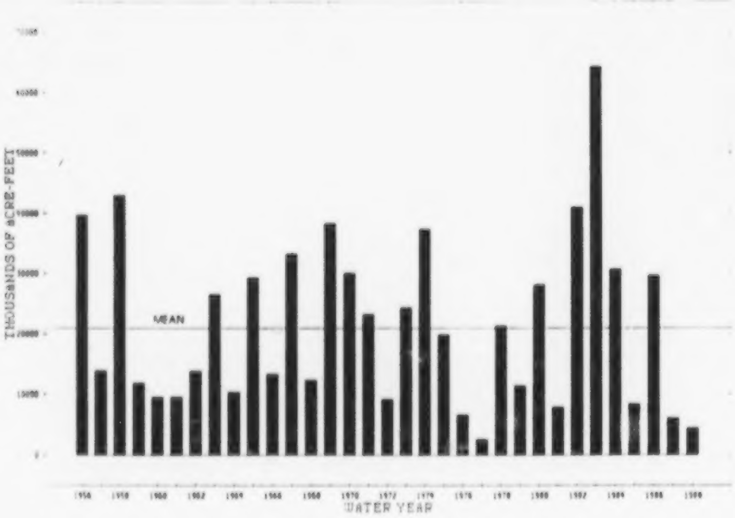
Over the years, the State Board issued numerous conditional water right decisions and permits—to the U.S. Bureau of Reclamation (Bureau) for its Central Valley Project and to DWR for its State Water Project—for the operation of water projects in the Delta.

Because of the complexity of issues and many unresolved questions surrounding the dynamics of the Delta, the State Board (and its predecessor, the State Water Rights Board) "reserved jurisdiction" when it issued permits to DWR and the Bureau for operations in the Delta. The purpose of this reservation of jurisdiction was to allow the State Board an opportunity to revise standards pertaining to salinity control, fish and wildlife protection and coordination of the state and federal projects as more information was developed.

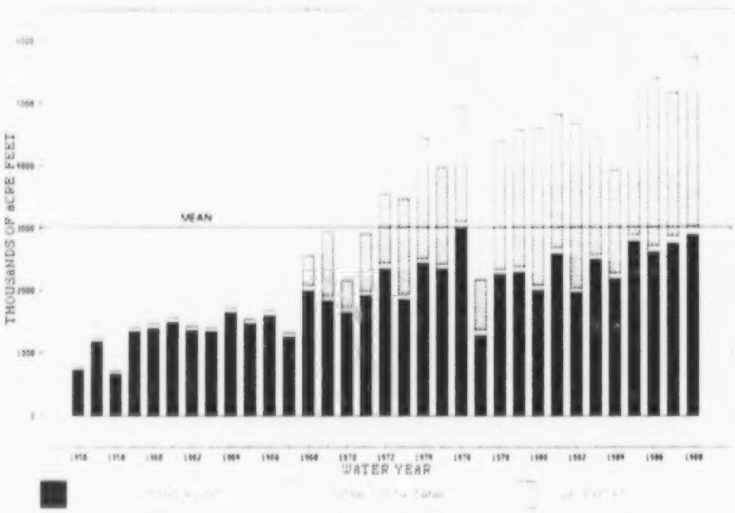
In August 1978, the State Board exercised its reservation of jurisdiction over the water right permits of DWR and the Bureau by adopting D-1485. At the same time, the State Board adopted a new water quality control plan (the Delta Plan) for the Sacramento-San Joaquin Delta and Suisun Marsh. Together, the two documents revised existing standards for flow and salinity in the Delta and required DWR and the Bureau to meet these standards (allowing 5 million acre-feet Delta outflow), either by reducing export pumping or by releasing waters stored in upstream reservoirs—or both. An underlying premise of D-1485 and the Delta Plan was that water quality should be at least as good as it would have been had the state and federal projects not been built.

The beneficial uses protected under these quality standards fall into three broad categories - fish and wildlife, agriculture, and municipal and industrial uses - and water quality standards were established for each of these. The standards provide adjustments for lowered quality in critical or dry years, when less water is flowing into the Delta from the rivers which feed it.

NET DELTA OUTFLOW (TAF)
FOR WATER YEARS 1956-1988



DELTA EXPORTS (TAF)
FOR WATER YEARS 1956-1988



At the time D-1485 and the Delta Plan were issued, the State Board stated it believed the level or protection afforded was "reasonable." However, because it recognized that there was continuing "uncertainty associated with possible future project facilities and the need for additional information," it stated that it would review the Delta Plan in ten years. It also called for additional fisheries and water quality studies and sampling and monitoring programs in an attempt to gain a better knowledge of the ecosystem and water quality needs for Delta agriculture, and to find answers to some of the persistent questions. For the first time the State Board mandated studies of the projects' impacts on San Francisco Bay.

Both the Delta Plan and D-1485 stated the State Board's intent to reopen the matter in order to review this additional information and to reassess the standards.

In mid-1987, as the next step in this evolutionary process, the State Board began an extensive hearing procedure, the Bay-Delta Hearing (later called the Bay-Delta Proceedings), aimed at developing new water quality objectives for the Bay-Delta estuary and the means for implementing them. During the first six months of this multiyear process, its members heard testimony on a number of issues. Over the coming months and years, this evidence will be assessed, and a salinity control plan and pollutant policy document prepared.

Ultimately, the 1978 Water Quality Control Plan and Water Right Decision 1485 (D-1485), which together set water quality and flow standards for the Delta, will be revised and possibly expanded to include San Francisco Bay. (See page 17. Bay Delta Proceedings.)

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Racanelli Decision

In 1986 an historic decision of the state Court of Appeal (known as the Racanelli decision) concluded that the State Board in issuing D-1485 had improperly narrowed its scope of its water quality planning to the protection of water rights (instead of the protection of all beneficial uses of Delta waters) and to the impacts on water quality of the state and federal projects (instead of the impacts of all factors and water users affecting water quality in the Delta).

This ruling, allowed to stand by the California Supreme court, instructs the State Board, when establishing water quality objectives for the Delta, to take into consideration all factors - not just the operation of the state and federal projects -which have a bearing on Delta water quality. The decision also said the State Board had improperly based its previous salinity objectives on levels which are needed to protect existing water rights, rather than determining what flows and salinity are needed to protect the various uses of Delta water.

The ruling distinguished the State Board's water rights and water quality planning authorities. In doing so, the court paved the way for more comprehensive water quality objectives and a broader program of implementation to obtain those objectives, including the regulation of non-project water rights and the recommendation of other non-regulatory measures.

The Public Trust

A 1983 California Supreme Court decision focusing on the Los Angeles Department of Water and Power's diversion of water from the streams that feed Mono Lake overlaid the California water rights system with the age-old English Law doctrine of "Public Trust," through which a state is required to hold in trust for future generations the values associated with certain resources.

The decision essentially charged the courts and state agencies, including the State Board, with the obligation to act as guardian or "trustee" for the beneficial uses dependent upon the public's water resources. The court noted its previous expansion of the concept of the public trust doctrine to include not only the traditional uses of navigation, commerce, and fishing but also "changing public needs of ecological preservation, open space maintenance and scenic and wildlife preservation." Additionally, the court held that the public trust doctrine applies to diversions from streams tributary to navigable waters when such diversions may harm public trust uses of the downstream navigable waters.

In its presently developed form, the public trust doctrine requires the courts and the State Board to perform a balancing test to weigh the value to society of a proposed or existing water diversion against protection of the public trust uses of water. Public trust issues and values associated with the Delta are figuring more prominently in the current Bay-Delta Proceedings than in past Delta decisions.

Interagency Agreements:

Coordinated Operation Agreement

In 1986, DWR and the Bureau replaced 26 years of year-to-year agreements regarding the responsibilites of each project in the Delta with a Coordinated Operation Agreement (COA).

The agreement gave additional safeguards to the fragile Delta by committing the Bureau to a share of the responsibility for sustaining flows in the Delta during dry periods.

A major hurdle in reaching agreement was the federal government's reluctance to set a precedent by accepting the state's authority to prescribe water quality requirements for the Delta to be met by the CVP. The concern was resolved by a provision in the COA which authorizes the Secretary of the Interior to determine if operating the CVP to meet new state Delta standards would be inconsistent with Congressional directives. If the Secretary were to make this determination, the U.S. would be required to bring a legal action to decide whether the state standards for the Delta apply to the federal CVP.

Cooordinated operation is vital for both projects to make the best use of their facilities, but had long been controversial. In times of drought prior to its implementation, the SWP may have been forced to sacrifice the needs of some of its customers to meet State Board Delta flow and water quality standards, if the Bureau did not voluntarily agree to contribute water to meet those standards. Under the COA, the federal government is committed to share with the state the responsibility to meet most of the water quality and flow standards established in D-1485, as well as future Bay-Delta standards, subject to provision in the agreement.

Agreements

Bay-Delta Proceedings

The State Water Resources Control Board (State Board), through Regional Water Quality Control Board two and five, has primary responsibility for water quality objectives with the Bay-Delta estuary. The State Board in 1987 began a comprehensive procedure aimed at developing new water quality objectives for the estuary and the means for implementing them. After gathering voluminous, and often contradictory, evidence and testimony from over 60 organizations and interest in Phase I of the proceedings, the State Board released in late 1988 a draft Salinity Control Plan and Pollutant Policy Document.

To say the draft plan and document were not well received is an understatement. Fishery and environmental interests involved in the Proceedings, concerned over declines in certain fish populations and supportive of promptly enacted, stronger Delta standards, felt the drafts did not give enough water to instream uses to protect the estuary's resources. And urban and agricultural water users, supportive of additional development to increase supplies to an ever-growing state (or at the very least no reduction in already committed supplies), saw the drafts as limiting their supplies.

The drafts were subsequently withdrawn, and the proceedings were redesigned to include workgroups through which interested parties and SWRCB staff could further investigate alternatives aimed at balancing all of the various uses to which the Delta's water are put.

The outcome of the proceedings, now scheduled for completion in 1993, is important not only to users of the Delta's waters, but to all Californians as well because most of California's water delivery systems are interconnected to some degree.

Suisun Marsh Preservation Act and Agreements

In 1987, state and federal representatives of DWR and the Bureau signed an agreement intended to maintain the brackish character of the 57,000 acres of waterways in the marsh, northeast of Carquinez Strait. The marsh is a primary resting place and feeding ground for millions of waterfowl migrating on the Pacific Flyway. The agreement is intended to mitigate for changes in the marsh caused by operation of state and federal water projects and by other upstream diversion of fresh water. The Bureau and DWR will each pay 40 percent of the costs of marsh improvements, and 20 percent will be allocated to other upstream users and reimbursed by the legislature. To date, approximately $40 million has been spent on marsh improvements.

Fish Agreement

Another area of concern in the Delta was addressed when DWR and the state Department of Fish and Game (DFG) signed an agreement in 1986 aimed at offsetting some of the direct fish losses at the Delta pumping plant. Because water and fishery interests agreed that fish losses are probably greater today because of past operation of the SWP, the state water contractors agreed to provide an additional $15 million for a program to quickly increase Delta fish populations. The agreement sets up a procedure to calculate direct fish losses on an annual basis and requires DWR through its contractors to pay for mitigation. These payments have totaled about $2 million per year and will continue indefinitely until another agreement supersedes.

The fish agreement was seen as an integral step in the installation of four new pumps at the Harvey O. Banks Delta Pumping Plant. The pumps, which are now being built, are expected to eventually provide increased pumping capacity for the State Water Project and act as a backup in case of other pump failures. A new Corps of Engineers permit and new agreement with DFG are needed to increase pumping levels. DWR Director David Kennedy approved the pump project in 1986 based on an Environmental Impact Report prepared by the department. The four pumps will bring the total number of Delta pumps to eleven and will be built at a cost of $46 million by 1991.

Plans and Programs

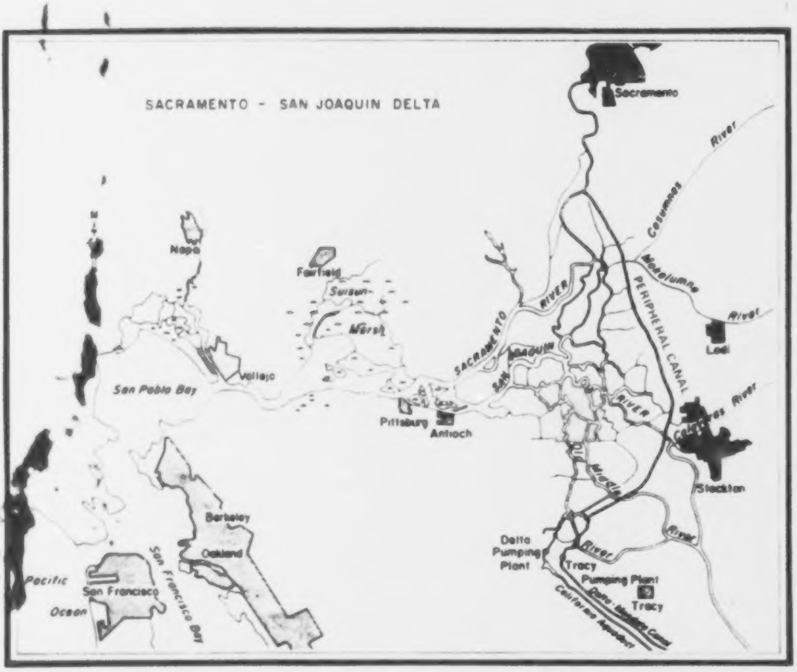
The Peripheral Canal and Delta Channel Studies

In 1977, the Department of Water Resources proposed and amalgam of joint state-federal programs and facilities, later called Senate Bill 200, which included the Peripheral Canal, Suisun Marsh protection facilities, on- and off-stream water storage facilities in the Sacramento and San Joaquin valleys, ground water recharge and storage in southern California, wastewater reclamation and increased water conservation.

As proposed, the 42-mile-long Peripheral Canal of SB 200 would have carried water diverted from the Sacramento River around the eastern edge of the Delta to CVP and SWP pumping plants and Contra Costa Canal intake on the southern edge, and released fresh water into the Delta at strategic points for irrigation, fish and wildlife and repulsion of salt water. Although large quantities of Sacramento River water would have been diverted into the canal, supplies of water would still flow past the canal intake on the river and down into the Delta and San Francisco Bay.

Proponents contended, among other things, that the canal would eliminate reverse flows in the Delta, easing conditions for fish. Canal foes expressed a fear that the facility would lead to more exports and further reduction in the flow of fresh water to the Delta and Bay resulting in harm to Delta and Bay consumptive and instream uses. In 1980, opponents of the canal and SB 200 mustered enough signatures to force a referendum on the bill. The ballot measure, called Proposition 9, was scheduled for the June 1982 ballot and the battle lines were drawn. As a compromise to some northern Californians, a provision was added to SB 200 guaranteeing more protection for the Delta and North Coast rivers. If Prop. 9 failed, however this protection would not go into effect.

Statewide, in 1982 Proposition 9 was rejected by voters 62 to 38 percent. In the tally, 50 of the state's 58 countries voted against the measure, leaving only Kern and the seven counties south of the Tehachapis in favor. In 35 northern counties, the "no" vote exceeded 90 percent.



Proposition 9 was the biggest water package to be presented to the voters in more than 20 years. Its rejection made an impact on the direction of water resources planning in California that is still being felt years later. The battle for and against Prop 9 was one of the most expensive and divisive in California's 100-year battle over water. Many argue that the size of its financial package was responsible for its defeat.

Following defeat of the Proposition 9 package there have been other attempts to approve a water transfer facility in the Delta. In late 1983, the Deukmejian administration proposed four Delta alternatives to the Peripheral Canal, described in DWR's "Alternatives for Delta Water Transfer" bulletin.

One was chosen and in 1984, SB 1369, one of eight bills in Governor Deukmejian's Water Package, was carried in the Senate by Senator Ruben Ayala, chairman of the Senate Committee on Agriculture and Water Resources. The bill, co-authored by Assemblyman Jim Costa, chairman of the Assembly Water, Parks and Wildlife Committee, was estimated at $1.1 billion and included construction of a new 10- to 14-mile-long canal linking the Sacramento and Mokelumne Rivers (the New Hope Cross Channel, or "Duke's Ditch," as it was dubbed by opponents), widening existing Delta channels, construction of three additional reservoirs south of the Delta as well as investment in levee maintenance and fishery restoration. If completed, the SB 1369 package would have moved an additional 630,000 acre-feet a year through the Delta to the San Joaquin Valley and southern California. In August of 1984, however, the Governor dropped the bill when it became clear it would not receive enough support in the legislature and might be subjected to a voter referendum.

Another Delta bill focused on offstream storage below the Delta. Legislation introduced by Assemblyman Phil Isenberg in 1984 authorized the construction of a major storage reservoir near the existing San Luis reservoir in Merced County. This Los Banos Grandes Reservoir would be used by the state during high runoff periods to store surplus water that otherwise would flow out to sea. The reservoir's greatest benefit to the Delta, according to DWR, would be increased flexibility of operation that could help offset the impacts pumping has on Delta fish, one of the biggest concerns in operation of the SWP.

By 1989 DWR had completed five years of feasibility studies for the reservoir, now conceived as having 1.7 million acre-feet storage capacity. The reservoir has evolved into a joint SWP/CVP project with the Bureau serving as the lead federal agency in preparation of the necessary environmental documentation. Key to this reservoir project are increasing channel capacity, an agreement with DFG and the addition of the final four pumps at the state's pumping plant, since the feasibility study is based upon the assumption the plant will be completed. A final Environmental Impact Report for the project is scheduled to be completed by 1990.

The planning and environmental documentation process necessary to obtain regulatory permits for three separate Delta Water Management programs—South, North and Western—was started by the Bureau and DWR in 1987 with public meetings and will take approximately four years to complete.

In an effort to find long-term solutions to improving and maintaining water levels, circulation patterns and water quality in the southern Delta, DWR and the Bureau have initiated planning activity to evaluate alternatives to meet these objectives. They include: dredging and channel improvements; channel flow control structures; relocation of the Contra Costa Canal intake; changes to Clifton Court Forebay, including a new intake gate or relocation of the intake and enlargement of the forebay; and interconnection of the CVP with the forebay. A Corps of Engineers permit to allow greater exports for water banking will also be part of this program.

North Delta planning will focus on providing flood protection for islands along the lower Mokelumne River, reducing fisheries impacts, and improving transfer efficiency of federal and state project water across the Delta. One promising possibility for the northern Delta is a phased program that would start with enlargement of the South Fork of the Mokelumne River, providing major flood control benefits for the area, and correcting unfavorable flow patterns caused by state and federal pumping.

DWR and DFG are also investigating West Delta water management needs, the objectives of which include minimizing oxidation and subsidence, improving levees and protecting existing highways and utilities, providing habitat for waterfowl, improving recreation, reducing fish impacts by screening, and protecting Delta water quality. One alternative is a wildlife management plan which would change Sherman Island from current cultivation practices to managed wildlife habitat, reducing subsidence and flooding problems.

Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary.

The interagency program was initiated in July 1970 by a Memorandum of Agreement between the California Departments of Fish and Game (DFG) and Water Resources (DWR), the U.S. Bureau of Reclamation (Bureau) and the U.S. Fish and Wildlife Service (FWS). Later, the U.S. Geological Survey (USGS) and State Water Resources Control Board were brought into the program as participants. The program was an outgrowth of testimony at the water rights hearing leading to D-1379 (preceding D-1485), which indicated that construction and operation of the SWP and CVP may have been contributing to fish and wildlife problems in the estuary. The testimony also indicated a need for more information regarding the environmental needs of fish and wildlife and ways to design and operate the water projects to minimize detrimental effects on those resources.

Over the years, annual reports have been submitted to the State Board and other agencies.

Aquatic Habitat Institute

The Aquatic habitat was established at the recommendation of the State Water Resources Control Board in 1982 in recognition of the need to develop a more comprehensive scientific understanding of the impacts of human activities on the ecology of the Bay and Delta. Set up as an independent, nonprofit corporation with the purpose of evaluating the effects of pollution on the estuary, AHI's charge is to coordinate research and monitoring efforts related to pollutants in the estuary, and publish research and findings.

Funded by the San Francisco Estuary Project (See below), AHI has developed computer databases compiling research and monitoring programs that have been, or are presently being, conducted in the Bay-Delta estuary, and testimony and exhibits presented during the State Water Resources Control Board's Bay-Delta Proceedings. Interested parties may access the databases at no charge.

San Francisco Estuary Project

In 1986, the San Francisco Bay-Delta estuary was added to the U.S. Environmental Projection Agency's (EPA) National Estuary Program. The program was formerly established and funded under the federal Water Quality Act of 1987 with the purpose of protecting and improving water quality and enhancing living resources in the nation's designated estuaries. Representatives from the public sector, all levels of government and elected officials from 12 Bay-Delta counties are working together in the five-year project to develop a comprehensive and water conservation management plan for the estuary. This requires characterizing the problems and values of the estuary by collecting and analyzing information, developing a data management system, evaluating existing laws and recommending corrective actions. The plan will then go to the governor and EPA for approval.

The project is investigating five issues within the estuary: the decline of biological resources; increased pollutants; freshwater diversion and altered flow regime; increased waterway modification; and intensified land use. Status and Trends Reports on each of these issues are currently being prepared, with public workshops beginning in 1989.

Summary

Obviously, there are no simple solutions to the Delta dilemma. The myriad of different agencies, all with different mandates, all attempting to come up with solutions for Delta problems, often work at cross purposes. A multiplicity of issues and special interests has caused a long and drawn-out process of addressing and solving Delta problems and state water issues. Each problem is as important as the next. Competing interests for the water flowing through Delta channels further complicate the issues.

The Delta is the crucial mingling point for much of the state's runoff and therefore is a critical link in the chain of events which must ultimately assure all of California an adequate water supply. But the Delta is a dynamic and unique estuary as well, with inherent value as more than a mere water conduit. And for many environmental organizations, Delta issues have become a battle cry; the Delta has a symbolic quality that transcends the issues.

The productivity of the rich Central Valley depends on the transportation of water in the Sacramento Valley, through the Delta and into the San Joaquin Valley. In addition to upstream and local Delta uses, one-fourth of the land area and two-thirds of the population of the state are served, at least partially, by water exported from the Delta.

Many southern California water users look to the Delta and surplus northern supplies to offset lost supplies from the Colorado River. As a result of a 1963 U.S. Supreme Court decision, California's entitlement to Colorado River water was reduced from 5.3 to 4.4 million acre-feet per year. Now that Arizona has begun using its Colorado River entitlement, the Metropolitan Water District of Southern California (MWD) has lost more than half of the water available to them in the past, although supplies are being met by surplus water. One highly controversial proposal to ease the Southland's water shortage, which might also help lessen pressures on the Delta, suggests transfering water conserved by agricultural users to the thirsty coastal cities.

State Water Project users in the San Joaquin Valley expanded agriculture upon the arrival of state project water and argue that they depend upon the state's commitment to complete the SWP. They say if state project water deliveries aren't increased in their area, ground water overdraft will increase as in pre-project days, especially during droughts, and agricultural land will go out of production.

In addition, over half of California's anadromous fish, such as striped bass and salmon which live in the ocean but travel to freshwater to spawn, are dependent on the waters of the Delta. Protection of these fish, and the estuary's ecosystem, adds still another dimension to the problem of satisfying all the Delta's water interests.

And finally, Delta water users maintain that protection of the Delta and adequate supplies for Delta users should be placed foremost.

In the wake of the defeat of Prop 9 and the Governor's "Ditch" package, however, there has been a shift toward healing old wounds and building consensus. Coalitions of northern and southern Californians, urban and agricultural users, and environmentalists are actively seeking accommodations aggreeable to all interests, hoping that with the right checks and balances, and with proper management, the state's water needs can be met without jeopardizing the environment.

But so far, each proposal for solving the Delta's quagmire of problems seems to be met with opposition from some region or group, resulting in continued negotiations and discussions but delaying crucial Delta solutions.

In the meanwhile, many believe there is a strong possibility that nature may reclaim the Delta—through subsidence, a large earthquake or a gradual raising of the sea level due to global warming—to the wetlands area it once was. Were this to happen water quality issues would be raised to a crisis point for the millions of Californians who depend on it for their water, and arguments over prioritizing the best uses of the Delta's waters would prove immaterial.

Amid all this uncertainty, the Delta today still holds as much mystery and challenge as it must have held for its original settlers. And it remains apparent that the ever-changing Delta will continue to provide challenges in the years to come.

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Layperson's Guide to Agricultural Drainage

Prepared by the Water Education Foundation

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Updated 1991

On the Cover:

A field of cotton is being irrigated on the west side of the San Joaquin Valley. In this area, about 1.2 tons of salts are deposited on the topsoil of one acre of farmland from irrigation water. Agricultural land can be ruined permanently if irrigation continues and natural or artificial drainage and leaching of salts from the root zone does not occur.

The Layperson's Guide to Agricultural Drainage is prepared and distributed by the Water Education Foundation as a public information tool. It is part of a series of Layperson's Guides which explore pertinent water issues in an objective, easy-to-understand manner.

The mission of the Water Education Foundation, an unbiased, nonprofit organization, is to develop and implement education programs leading to a broader understanding of water issues and to resolution of water problems. For more information on the Foundation's materials contact:

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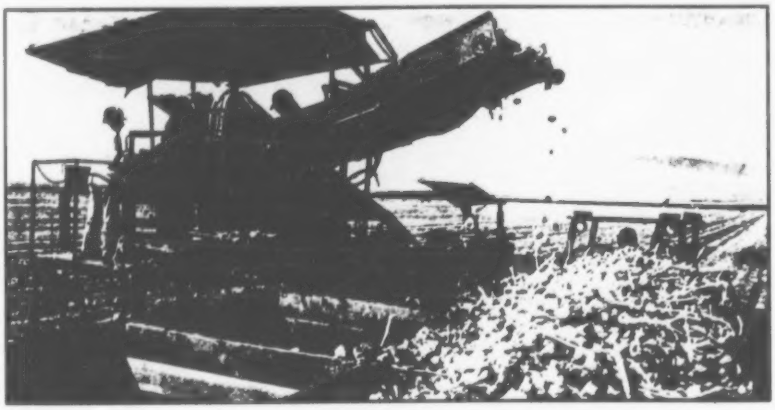
U.S. Bureau of Reclamation

Varied in climate, terrain and people, the prosperous Golden State produces more goods and services than all but five of the world's nations. Its agricultural industry has transformed millions of acres of arid land into fields and orchards with the help of irrigation projects that import water from less arid parts of the state and from the Colorado River. Today, farming is second only to tourism as California's top industry. Agriculture is also a major employer, with more than 80,000 families and as many as 400,000 workers growing and harvesting crops. According to the California Farm Bureau Federation, one out of every three people employed in California works at an agriculture-related job.

In 1990, California farmers sold $18.3 billion worth of food and fiber. But all this productivity does not come without a price. The arid climate that provides the almost year-round growing season also can hasten deterioration of irrigated soils. In some arid regions there is inadequate rainfall to wash **salts** from the soil. This, combined with especially high rates of evaporation and **transpiration**, cause minerals and salts to accumulate in the soil near the plant's roots. In parts of the San Joaquin Valley, a third factor, relatively impermeable layers of clay, complicates the drainage problem by inhibiting the downward movement, or **percolation**, of irrigation water. When poorly-drained saline soils are irrigated, shallow, salty ground water accumulates and eventually rises into the root zone. Without adequate drainage, a field can become waterlogged, like a flowerpot without a hole, stunting plant growth and reducing agricultural productivity. Underground drainage facilities provide the "hole," allowing farmers to flush excess salts from the soil while keeping the root zone from becoming waterlogged, thus preserving the soil's productivity. The saline water from underground drainage facilities, however, must go somewhere; therein lies one of the most difficult issues facing California's agricultural industry today.



Public awareness of the potential dangers associated with drainage water began to develop in 1984 when dead and deformed waterfowl were discovered at the Kesterson National Wildlife Refuge. Scientists directly linked the problem to toxic concentrations of trace elements contained in the drainage water used to supply the refuge's wetland areas. Awareness and concern have increased as more recent studies have shown that environmental problems associated with drainage water are widespread throughout the western United States. Some experts fear the damage has only begun to surface. Stepped-up research efforts and expanded water management programs focusing on minimizing the volume of agricultural drainage water while preventing **salination** of cropland are underway at water districts, public agencies and universities.

Salination — the buildup of salts in soil — is one of mankind's oldest environmental problems, resulting in reduced crop productivity and sometimes contributing to the decline of civilizations. The Middle East's Tigris-Euphrates Valley once was known as the "fertile crescent." Today it is mostly desert, partly because of the salinity of its soils. Similar examples of salination can be found in India, Pakistan, Egypt, the Soviet Union, China and Mexico.

In ancient times, the common remedy for salination was to stop irrigating and abandon the land until rains could flush enough salts from the soil. Then farming could be resumed for a few seasons until the salts built up again. This practice is still followed in some parts of the world.

In California, like most regions where irrigated agriculture is high-technology, water beyond that required to meet the crop's needs is applied to **saline soil** to wash, or **leach**, excess salts from the root zone. Leaching is the last step in resolving salination problems only where soil drainage is good. Where soils are not naturally well-drained, further assistance often is required. Two of the state's largest agricultural areas, the western San Joaquin Valley in the central part of the state and the Imperial Valley to the south, are faced with both poorly-drained and naturally-saline soils.

This Layperson's Guide, part of a continuing series published by the Water Education Foundation, reviews the science of agricultural drainage, explores regional drainage problems and remedies in several key areas and discusses what is being done to uncover workable solutions to drainage problems.

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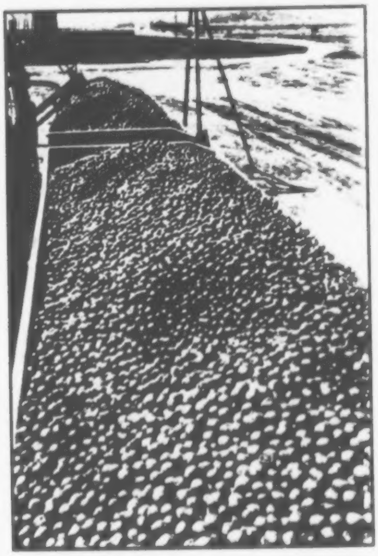
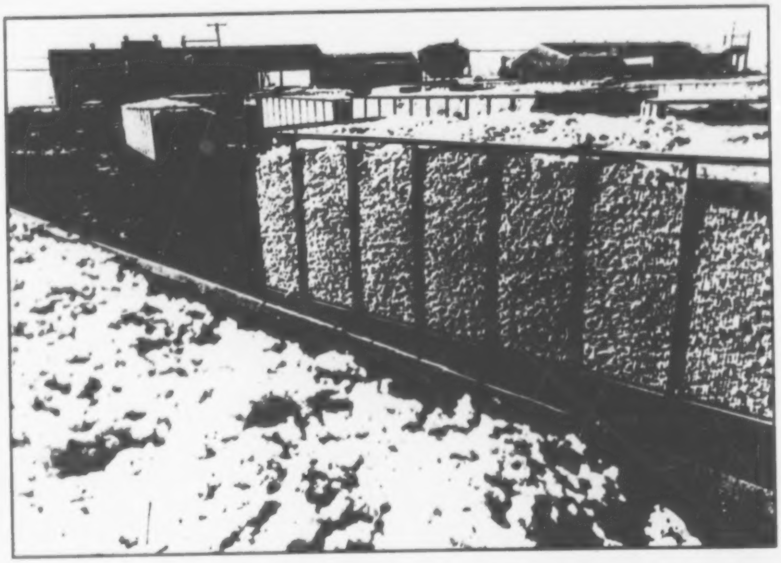




GLOSSARY

Bioaccumulation — The process by which an individual organism concentrates a substance within its tissues to a level greater than that found in the surrounding environment.

Bioconcentration — The process by which a substance is passed up the food chain resulting in an especially high level of the substance at upper levels of the food chain.

Cogeneration — Process by which energy is extracted from the waste heat of an industrial process such as a steam boiler or food processing system.

Electrical conductivity (EC) — One way of measuring the salinity of water, commonly expressed as millimhos per centimeter (mmho/cm) or deciSiemens per meter (dS/m), equivalent terms. EC can also be related to osmotic pressure, which influences the amount of water a plant's roots can extract from the soil. One mmho/cm or dS/m corresponds to about 640 parts per million (ppm) total dissolved solids.

Infiltration — The passage of water through the soil surface, into the soil.

Ion exchange unit — Device which selectively removes unwanted charged particles (ions) from a solution by attracting the ions to an oppositely charged site in the unit.

Leach — To apply water in excess of a crop's needs for the purpose of flushing out salts from the root zone. The leaching requirement is the amount of water needed to pass through the root zone to prevent salinity in the soil from reaching levels which would damage crop productivity.

Percolation — Movement of water down through the soil toward the water table (the level at which water stands in a well).

Potable — Suitable for drinking.

Reverse osmosis — Process for removing salts and other trace elements from water by forcing fluid through a membrane designed to allow only fresh water to pass. Salts and trace elements are concentrated, reducing the volume for disposal but still presenting some environmental management challenges.

Salination — Process by which salts accumulate in soil.

Saline soil — Soil affected by soluble salts.

Salts — All the minerals dissolved in water.

Selenium — Naturally-occurring inorganic element found primarily in soils, and to a lesser extent in water and air. Selenium is a necessary nutrient in very small amounts but can be toxic in high doses.

Solar ponds — System of saline ponds designed to extract energy from water when heated by the sun.

Subsurface drainage system — System of underground pipe to remove excess water accumulating below the soil surface, which will not naturally percolate downward, out of the root zone.

Transpiration — Process by which plants release water vapor to the atmosphere through the pores of their leaves.

Volatilization — Process by which a substance is passed off as vapor, evaporation.

Drainage Primer

What are Salts?

Salts are combinations of common earth elements and compounds: calcium, magnesium, potassium, sodium, chloride, sulfate, carbonate and bicarbonate, nitrate, and others. When farmers talk about salts they refer to all the minerals dissolved in the water and present in the soil. Sufficiently diluted, salts are usually harmless for most water uses and may even be beneficial. Excessive amounts of dissolved mineral salts, however, are detrimental to most water uses, including agriculture. In areas affected by salt accumulation, the choice of crops is limited to salt-tolerant food and fiber crops, such as wheat and cotton. The salt tolerance of crops varies tremendously, ranging from salt-sensitive strawberries to cotton, which can tolerate 10 times more salinity in the root zone than strawberries before yields decline. Crops such as stone fruits (peaches, avocados) and vine crops (grapes) are particularly sensitive to sodium and chloride.

Salts are commonly measured in milligrams per liter (mg/l) or parts per million (ppm), units which are roughly equivalent. One ppm is one part of a substance dissolved in one million parts of water by weight. **Electrical conductivity** (EC) is another measure of the concentration of salts, with conductivity steadily increasing as salt concentrations rise.

Surprisingly large amounts of salt are carried in solution by some rivers. For example, the Sacramento River, as it flows past California's capital city, contains about 300 pounds of salts per acre-foot of water, or about 100 mg/l of salts. An acre-foot is approximately 326,000 gallons, or enough water to cover an acre of land one foot deep. An average household uses between one-half and one acre-foot of water a year. Measured at Imperial Dam near Yuma, Arizona, the highly-saline Colorado River contains about 2,000 pounds of salts per acre-foot, or 725 mg/l of salts. The San Joaquin River at Vernalis contains an average of about 960 pounds of salts per acre-foot (about 350 mg/l), but sometimes climbs as high as 1,500 pounds per acre-foot (545 mg/l).

In arid lands, soil salinity problems are compounded when large volumes of salt-bearing irrigation water are applied to soils which already contain salts. Some of the applied water evaporates from the surface of the field, leaving salts behind. The rest of the water penetrates the soil where much of it is taken up by crop roots and is transpired through the plant leaves, again leaving salts in the soil. In a single irrigation season on the west side of the San Joaquin Valley, for example, about 1.2 tons of salts are deposited along with irrigation water on one acre of farmland. And the effects are not temporary. The agricultural value of land may be permanently lost if irrigation continues and artificial drainage and leaching of salts from the root zone is insufficient.

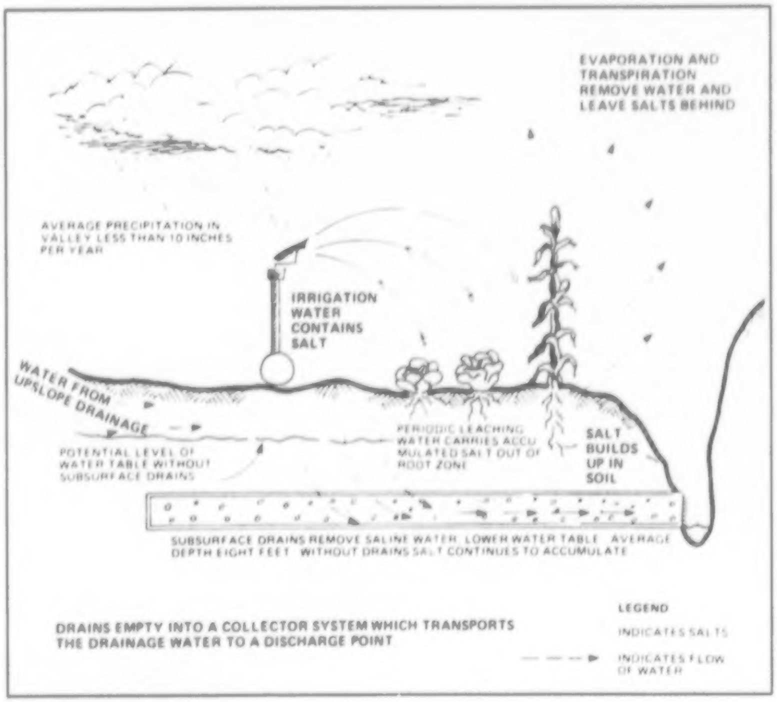
Need for Drainage

Plants, like animals, need food, water, air and a clean environment to live, grow and reproduce. Because most plants nourish themselves through their roots, a balance of life-sustaining materials must be maintained in the soil throughout the plant's root zone. Although tolerance to imbalances and toxic substances varies widely among plants, the productivity and ultimately the survival of all plants can be threatened by too much or too little of any of the materials needed to survive, or by concentrations of certain trace elements to toxic levels. Optimum plant productivity, the general goal of farmers raising a crop for market, is achieved by maintaining a rather specific balance of the life-sustaining materials. Careful mixes of fertilizer are applied at appropriate times in a plant's development. If rainfall supplies less than the needed volume of water to a crop's roots, a farmer often applies water via some method of irrigation. And if the soil retains too much water, not allowing sufficient air to reach the roots of the crop, artificial methods for draining the excess water from the root zone often are employed.

Artificial drainage also may be necessary if the farmer's soil or water supply contains elements that accumulate to concentrations harmful to the crop. Additional water beyond that needed to sustain the plant under normal circumstances is added to leach the harmful elements from the root zone. If a soil is freely draining, excess salts and water percolate deeply into the ground water basin. However, if an impermeable barrier exists, a **subsurface drainage system** is commonly used to carry excess salts and water away from the irrigated land helping to maintain the land's long-term productivity.

The amount of water required for adequate leaching varies widely with the salinity of both the soil and irrigation water, the salt tolerance of the crop, the uniformity of the field slope and other factors. The farmer usually must apply about 10 percent to 25 percent more water than the crop needs in order to cover the entire field and at the same time leach salts from the root zone — sometimes leading to charges that the farmer is wasting water. A favorable salt balance is achieved when salt is exported at least at the same rate as it is imported with irrigation water. In many basins, rivers are used as natural drainage systems to transport salts from agricultural lands. Thus, drainage becomes part of the flow of the river and is eventually carried to the ocean or an inland salt sink such as the Salton Sea. A prime consideration in these basins is whether salinity in the river can be kept below levels which may harm other uses of the river water or the fish and other wildlife which the river supports.

If salt levels are already beyond the capacity of a river to safely accept all of the drainage water, some or all of the saline water must be exported by man-made systems. The cheapest way to accomplish this is by using a gravity-flow canal to carry away the drainage water. The logical place to export salts is to a natural sink, where salts will not degrade fresh waters.


EVAPORATION AND TRANSPIRATION REMOVE WATER AND LEAVE SALTS BEHIND
AVERAGE PRECIPITATION IN VALLEY LESS THAN 10 INCHES PER YEAR
IRRIGATION WATER CONTAINS SALT
WATER FROM UPSLOPE DRAINAGE
POTENTIAL LEVEL OF WATER TABLE WITHOUT SUBSURFACE DRAINS
PERIODIC LEACHING WATER CARRIES ACCUMULATED SALT OUT OF ROOT ZONE
SALT BUILDS UP IN SOIL
SUBSURFACE DRAINS REMOVE SALINE WATER. LOWER WATER TABLE. AVERAGE DEPTH EIGHT FEET. WITHOUT DRAINS SALT CONTINUES TO ACCUMULATE
DRAINS EMPTY INTO A COLLECTOR SYSTEM WHICH TRANSPORTS THE DRAINAGE WATER TO A DISCHARGE POINT
LEGEND
INDICATES SALTS
INDICATES FLOW OF WATER

On-farm drainage system.

Coping with Drainage Water

Throughout the Imperial, Coachella and Central valleys, districts were established to deliver water to arid agricultural lands and to construct, operate and maintain regional drainage systems. In some areas, regional systems collect drainage water from individual farm drain outlets and convey the water to a point of reuse, disposal or dilution.

On-farm drainage management is the responsibility of the individual landowner. Most farms have some kind of surface drainage system and some have subsurface drainage systems. Irrigation districts, the U.S. Soil Conservation Services, county farm advisors, or agricultural consultants may assist farmers by recommending drainage system designs based on soil types, cropping plans and other considerations.

For years, subsurface drains have been called "tile" drains. Today, the term is a misnomer. While the first drain lines were made of baked red clay tiles and later of concrete, perforated plastic pipe came into use in the 1960s. Plastic is considerably less expensive, easier to install and seems to hold up just as well as concrete or clay. The cylindrical drain pipe, varying from three inches to 10 inches in diameter, is installed at a depth of six feet to 10 feet. Water then flows into and through the drain and toward the drainage outlet, where it goes into a surface drainage ditch or collector pipe and ultimately to a natural or artificial drainage conveyance system to dispose of the effluent.

Some drain lines are laid by machines which dig trenches, lay the drain and backfill the trench with gravel in a single operation. Another type of machine, the "mole" plow, bores into the soil and lays the drain without digging a trench.

In the Imperial Valley, where subsurface drains have been placed under much of the 500,000 acres under production, systems consist of large collector drains into which parallel lateral lines flow. Drains laid in sandy soil are spaced from 50 feet to 200 feet apart, while spacing in dense, heavy soil might be at intervals of 50 feet or less. Subsurface drainage is an expensive proposition, with initial costs running anywhere from $300 to $1,000 per acre, depending on the spacing and depth of the lines. Once laid, subsurface drain lines are not problem-free. The drainage process precipitates minerals like iron which can solidify and clog the system. Roots, too, can infiltrate the lines and partially or completely block water movement. Breaks or shifts in the system can permit soil to enter the drains, clogging them and causing sinkholes or washouts of the soil above the drain. To alleviate problems such as these, long hoses employing high-pressure jets of water can be threaded into the drains to dislodge obstructions.

Regional Issues

Imperial Valley

From an agricultural viewpoint, California's earliest drainage success story can be found in the Imperial Valley, the rich agricultural area located in the southeast corner of the state on the Mexican and Arizona borders. Yet here, as at Kesterson Reservoir and the Tulare Lake Basin farther north, trace element contamination and adverse effects on fish, wildlife and other beneficial uses are under investigation.

The Colorado River is the Imperial Valley's sole source of surface water. Before the introduction of irrigation water in 1901, the region was a vast desert, although its agricultural potential was recognized as early as the 1850s.

By 1902, U.S. Department of Agriculture engineers found that the valley's water table and salinity needed to be controlled, and by the 1920s it was apparent that a drainage problem existed. Accumulating salts and a rising water table forced some lands out of production and threatened the productivity of thousands of additional acres.

A $2.5 million bond issue was passed in 1922 for the area's water supplier, Imperial Irrigation District (IID), to begin constructing a drainage system to collect water from individual farms and transport it to the Salton Sea. Two northward-sloping river channels, the New River and the Alamo River, became the system's main drainage conveyance channels. IID began construction of an extensive system of open drains linking farms to the river channels. Today, IID maintains a network of more than 1,400 miles of open drainage ditches.

In the early days, farmers dug ditches on their land to help carry away salty drainage water, however, due to the fine texture of the soils, these ditches proved to be insufficient. Subsurface drainage systems were introduced in 1929. To date, 32,000 miles of subsurface drains have been installed on more than 60 percent of Imperial Valley farmland. About 867,000 acre-feet of agricultural drainage water flows to the Salton Sea annually, of which 214,000 acre-feet comes from tile drains.

Most recently, questions have been raised about the presence of toxic concentrations of trace elements in the waters and waterfowl of the Salton Sea, which serves not only as a repository for agricultural drainage water, but also as a wildlife habitat, sport fishing and recreational area. The U.S. Fish and Wildlife Service (USFWS) in 1986 found elevated levels of **selenium**, nickel, arsenic and lead in tissue samples from waterfowl that spend their winters in the Salton Sea. As a result, the USFWS is conducting in-depth monitoring and analysis of impacts in the area.

The Coachella Valley

IID's neighbor to the north, the Coachella Valley Water District, also operates and maintains an effective drainage system. Farmers in this agricultural oasis, which supplies almost all of the nation's dates, have installed extensive systems of subsurface on-farm drains. Today, more than 2,000 miles of farm drain lines serve approximately half of the valley's 78,500 irrigable acres. Like Imperial Valley, agricultural drainage from the Coachella Valley flows into the Salton Sea, although in a far smaller amount (an estimated 120,000 acre-feet per year).

The farm drainage waters are discharged into main collector drains (open ditches or underground pipe drains) constructed and maintained by the district. Large concrete pipe drains have replaced most of the district-maintained open drains. Substituting underground pipes has allowed additional cropland to be put into production and also has reduced operation and maintenance costs. Another benefit is reduced exposure of Salton Sea fish to fertilizers and pesticides that could more readily contaminate water in open ditches than in underground pipe.

Laying subsurface drainage pipe as part of a large, collector drainage system — the San Luis Drain.

7

The Sacramento-San Joaquin Delta is a rich agricultural region where many islands are below sea level, requiring farmers to pump water from their land.

The Sacramento-San Joaquin Delta

Few regions are as important to California's water supply as the Sacramento-San Joaquin Delta, where the Sacramento and San Joaquin rivers converge to discharge into the San Francisco Bay. This sprawling network of waterways serves as a system to supply and transport water to more than 19 million users in central and southern California. The Delta also is a rich agricultural area of about 700,000 acres and contains some of the most critical fishery and wildlife habitat in the state.

Because most of the Delta islands are below sea level, the area is beset by seepage-related drainage problems. Farmers must constantly pump water from their lands to permit crops to grow. However, farmers must also add controlled amounts of water for productive agriculture. Some of these farmers rely on the waters of the San Joaquin River for their irrigation supply. Here, drainage and water quality problems intertwine.

The salt content of drainage water flowing from the west side of the San Joaquin Valley is high and sources of dilution water are somewhat limited. Most of the valley gets an average of less than 10 inches of rainfall a year and water historically received from Sierra streams is now largely retained by dams and either exported or diverted for consumption. During the summer irrigation season, some stretches of the San Joaquin River consist almost entirely of irrigation return flows. The flows include surface runoff and subsurface drainage from irrigated east- and west-side lands and, to a lesser extent, from public and private wildlife management areas.

Exports of the Central Valley Project, Friant Project, East Bay Municipal Utility District and San Francisco's Hetch Hetchy Project all tend to increase the salt concentration in the San Joaquin River by reducing the amount of water available for dilution. According to the South Delta Water Agency, about 1.3 million tons of salt are deposited in the Delta annually from the San Joaquin River and the salt load is increasing at the rate of about 18,000 tons per year. Where river salt concentrates in the semi-isolated reaches of some south Delta channels, salinity reaches as high as 2,000 ppm salts during the summer months.

Selenium is also of concern in the Delta. Chemical analyses of plants, fish and waterfowl living in the Delta and San Francisco Bay indicate that selenium levels in the water may not appear to be excessively high. However, bioconcentration and the continued recycling of selenium transported to the area with agricultural drainage water and discharged with industrial and municipal waste water may be causing problems. According to the San Francisco Estuary Project's 1991 Status and Trends Report on Pollutants in the San Francisco Estuary, most of the estuary's selenium load comes from San Joaquin River flows. The report states that San Joaquin River flows deposit 4.2 metric tons of selenium into the estuary on an annual basis, municipal and industrial effluent accounts for the deposit of 2.1 metric tons and Sacramento River flows deposit 1.1 metric tons.

8

The San Joaquin Valley

The San Joaquin Valley is one of the most productive agricultural regions in the world. Crops grown there include grapes, tomatoes, hay, sugar beets, cotton and a multitude of other fruits and vegetables. In 1987 (the last year for national ranking) three San Joaquin Valley counties — Fresno, Tulare and Kern — ranked first, second and third in the nation in agricultural production. In 1990, the three counties' crop and livestock production was $2.94 billion, $2.16 billion and $1.84 billion, respectively.

Irrigation began in the San Joaquin Valley in the 1870s. As early as 1886, a wide-spread need for agricultural drainage in the valley was evident. In the 1890s and early 1900s, some cultivated lands were forced out of production because of salt and drainage problems. Although drainage problems were recognized early, farming continued to expand. Localized problems in some areas of the valley were controlled by using irrigation wells which lowered ground water levels. Areas with access to the San Joaquin River were able to use the river to convey agricultural drainage.

Soil salinity is predominantly a problem on the west side of the valley. Irrigation water used on the east side of the valley comes from Sierra Nevada snowmelt and rainwater and contains extremely low concentrations of dissolved salts (less than 100 mg/l). Also, soils on the east side were borne of granitic rocks which contain few salts and generally do not form clay layers that impede the downward flow of water. In great contrast, westside soils were formed from saline marine sediments eroded from the Coast Range and contain thin clay layers or lenses that impede **percolation**, creating numerous shallow water tables. Lands in the lowest part of this valley may be affected both by water applied to the land surface and by the horizontal flow of percolation water from irrigated lands upslope. The water supply to the west side is not highly saline (about 250 mg/l), but is significantly more saline than the Sierra snowmelt. In fact, according to 1990 data, approximately 1.6 million tons of salt per year come to the west side of the San Joaquin Valley with irrigation water imported from the Sacramento-San Joaquin Delta.

Today, the largest single district affected by the lack of access to drainage is the 600,000-plus-acres Westlands Water District (Westlands), the largest irrigation district in the United States. Westlands is located in the federal San Luis Unit service area on the west side of the San Joaquin Valley and is without drainage access to the San Joaquin River. Approximately 198,700 acres have a shallow saline water table between five feet and 10 feet from the surface. Saline water is less than five feet from the surface under 12,900 acres of the most severely affected land. At depths of less than 10 feet, saline water begins to seriously affect crop productivity.

Because of the severity of the problem, the district has been monitoring drainage conditions and annual crop production. Within its boundaries alone, areas with water tables shallower than 10 feet had crop production losses of $150 to $415 per acre, or approximately $35 million in 1987, the last year for which figures are available. This one district's losses translate to an annual income loss of roughly $70 million for the valley and $95 million statewide, including losses sustained by industries which provide goods, services and sales for the valley's farms and agricultural products.

The San Luis Drain

When the federal and state governments began laying the groundwork for large water supply projects to serve the San Joaquin Valley, planning also began for drainage facilities. In 1960, California voters approved financing and construction of the State Water Project and authorized the California Department of Water Resources (DWR) to construct drainage facilities as part of the project. That same year, Congress enacted Public Law 86-488 for development of the San Luis Unit of the federal Central Valley Project, which also called for construction of the San Luis Drain to meet the unit's drainage requirements.

Efforts were made for federal/state cooperation to build a joint drainage system, but there were several reversals in the state's planned participation in a valley-wide drain. In 1967, DWR notified the U.S. Bureau of Reclamation (Bureau) that the state would not participate, and requested the Bureau to proceed with a smaller drain to serve only the federal San Luis Unit service area.

Construction of the San Luis Drain began in 1968, but was halted in 1975 when funds ran out and concern over disposal of drainage water to the Sacramento-San Joaquin Delta heightened. By then, the Bureau had completed about 85 miles of the drain and the first stage of Kesterson Reservoir, which was to be managed jointly for irrigation drainage and wildlife habitat uses under a 1970 agreement with the USFWS. In 1973, Kesterson began receiving surface irrigation runoff. Subsurface drainage water was added to the flow in 1978. By 1981, subsurface drainage was the sole source of water to Kesterson Reservoir. Prior to conducting studies necessary to satisfy state requirements for the discharge of drainage water to the Delta, the Bureau reevaluated options for valley-wide drainage and salt management. In a cooperative federal/state effort in 1975, the Bureau, DWR and the State Water Resources Control Board (State Board) formed an Interagency Drainage Program (IDP) and jointly funded a four-year study. The IDP and a 30-member public advisory committee evaluated 18 alternatives, recommending a valley-wide drain that would incorporate the completed portion of the San Luis Drain. The project was to have included a 290-mile joint-use federal/state drainage canal to be constructed in stages. The existing 85-mile stretch would have been the center section. Construction of a northern extension to Suisun Bay was expected to follow by 1991, and by 2000 a section would have been completed to the south San Joaquin Valley. The collected drainage effluent was also planned to provide the water supply for a total of 64,300 acres of new or restored wetland wildlife habitat.

In 1980, the Bureau applied for a permit to discharge the drainage water at the location identified in the IDP report, near Chipps Island in the Delta. After the State Board identified the information needed to set discharge requirements, the Bureau began technical studies to gather necessary data. But plans to complete the drain were dashed by field observations made by the USFWS in the spring of 1983. A very high incidence of mortalities and deformities among Kesterson waterbirds revealed a new drainage problem — the effects of toxic concentrations of trace elements on the environment.

Typical view of a Kesterson Reservoir evaporation pond before clean-up and filling.

Problems at Kesterson Reservoir

In 1982, the USFWS discovered unusually high concentrations of selenium in fish at Kesterson Reservoir and in 1983 and 1984 turned up an alarming incidence of deformity and death among young waterfowl at Kesterson. Scientists concluded that selenium poisoning was the probable cause. These findings were the impetus for a wealth of studies into the potential effects of selenium and other drainage-related elements on the health of fish and wildlife and changed the course of drainage planning in the San Joaquin Valley.

Testing of the drainage water flowing into the reservoir revealed that selenium levels ranged from 85 to 440 ppb. The U.S. Environmental Protection Agency National Criteria Guidance indicates that levels of five ppb or less are necessary for the protection of freshwater aquatic organisms in flowing streams. State of California studies indicate that, in situations where aquatic life is continuously exposed to standing water, such as a marsh or pond, two ppb may be an appropriate allowable selenium level to protect aquatic life. And, if the selenium level of an evaporation pond reaches eight ppm, the State Department of Fish and Game will require that a hazing program be implemented to scare waterfowl from the area.

Although selenium in trace amounts is essential to all animal life, it has long been known to be harmful and even lethal in high concentrations. Fish and wildlife may become exposed to harmful concentrations of

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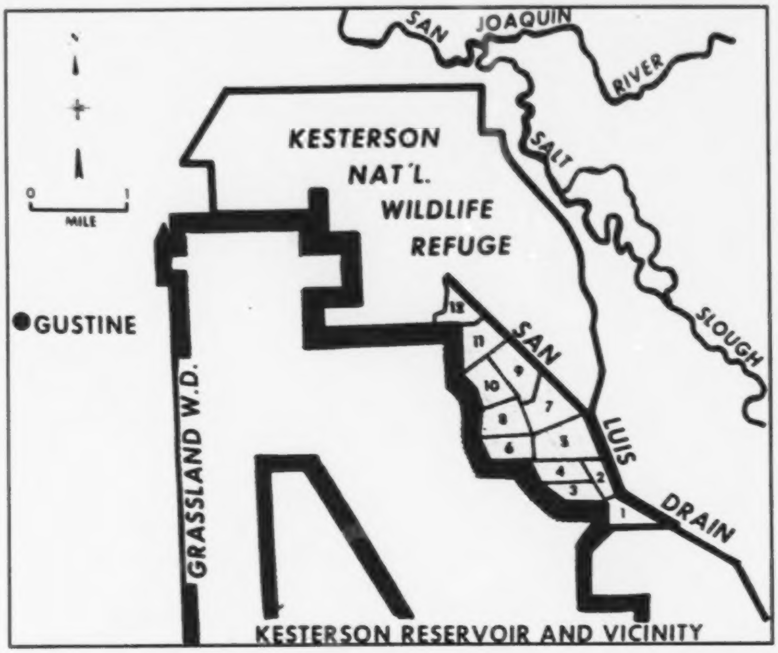
the element through two processes known as **bioaccumulation** and **bioconcentration**. Bioaccumulation occurs when an individual organism, usually a simple plant or animal, accumulates and stores selenium (or any other substance) in its body tissues at levels exceeding ambient environmental concentrations. When many of these organisms are consumed by species higher in the food chain, their stores of selenium are passed on. Through this second process, known as bioconcentration, progressively higher concentrations of the element are passed up the food chain. Eventually, selenium can attain levels in the tissues and organs of more complex organisms which limit reproduction and cause deformities and possibly death among waterfowl, other bird life and fish.



The 5,900-acre Kesterson National Wildlife Refuge includes 1,280 acres of filled evaporation ponds where selenium contamination is the most severe. The refuge also has 4,620 acres of viable wildlife habitat served with water from the federal Delta Mendota Canal.

To reduce the number of birds exposed to the contamination at Kesterson, the USFWS, in 1984, began a hazing program which involved firing blanks from guns to make noise and scare birds from landing at the reservoir. This program continues on a very limited basis today, primarily in the spring and late summer.

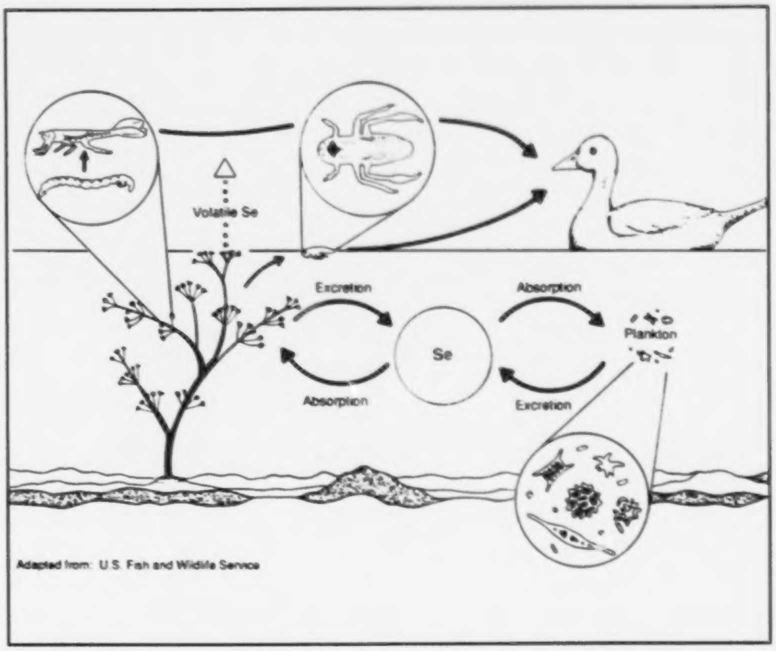
The Bureau's Kesterson Program was established in 1985 to identify and evaluate alternatives to solve problems at the reservoir. In May of the same year, a local landowner petitioned the State Board to issue "cease and desist" and "cleanup and abatement" orders for Kesterson. The following February, the State Board unanimously decided that under state law, drainage discharge into Kesterson was a "hazardous waste" because of its threat to human health and the environment. As a result, the Bureau was ordered to close Kesterson Reservoir or to upgrade the facility to a hazardous waste surface impoundment.

Then, on March 15, 1985, Secretary of the Interior Donald Hodel ordered immediate steps to begin closure of the reservoir and to discontinue irrigation water deliveries to the 42,000 acres from which the bulk of the drainage water originated, stating that continuing to operate the reservoir could cause Department of Interior employees to be in violation of the Migratory Bird Treaty Act, a criminal statute. Landowners and merchants feared that tens of thousands of acres of farmland might be put out of production and crops in place would be lost.

Relenting somewhat, on April 3, 1985, the Interior Department entered into an agreement with Westlands to phase out drainage flows into the San Luis Drain and Kesterson Reservoir by June 30, 1986. Westlands proposed to accomplish this through an intensive water conservation program, diluting and recycling drainage water and plugging a portion of their drainage collector system.

In the meantime, the Bureau and the USFWS began preparation of an Environmental Impact Statement (EIS) to analyze the differences in environmental effects of alternative methods of dealing with the cleanup of Kesterson Reservoir and the San Luis Drain. The EIS also examined the requirements and options for removing contaminated soil, ground water and vegetation from the reservoir and methods for disposal of contaminants. Once drainage flow into the reservoir was halted, the water in the 12 evaporation ponds which collectively make up Kesterson was allowed to evaporate.

In March of 1987, the State Board approved a scrape and burial plan requiring the Bureau to excavate most of the selenium-contaminated soil from the ponds at Kesterson and dispose of it in a 45-acre double-lined



Adapted from: U.S. Fish and Wildlife Service

Simple organisms (lower right) can bioaccumulate selenium and other substances in their body tissues. More complex organisms (moving clockwise) consume many simpler plants and animals and may bioaccumulate harmful substances.

and sealed landfill to be built at the reservoir site. The Bureau's cost estimates of the disposal procedure have ranged from $37 million to $144 million. Plans for excavation by the Bureau were halted when Congress questioned the cost and effectiveness of the proposed plan and study results indicated that the planned on-site disposal actions would not achieve cleanup goals at Kesterson Reservoir. In July 1988, the State Board acknowledged the likely ineffectiveness of the on-site disposal plan, extended the time for the Bureau to develop a final cleanup plan, and required the Bureau to proceed to fill all areas of anticipated ephemeral pools (depressions). The Bureau awarded a construction contract to fill about 600 acres of ephemeral pools at Kesterson Reservoir which flood with up-welling ground water. The procedure was completed in November 1988.

The final cleanup plan for Kesterson, approved by the State Board in September 1989, has three components: 1) active site management to prevent the reestablishment of wetland habitat which might develop from surface ponding of rain water; 2) minimizing selenium exposure to wildlife and monitoring any impacts; and 3) conducting research into selenium dissipation techniques.

Since the pools were filled and standing water was eliminated at Kesterson, no serious selenium-related effects have been observed in birds or mammals. However, insects and wild mushrooms growing in the soil-filled ponds have been found with abnormally high levels of selenium. Wildlife agents are concerned that when California's drought ends and heavy rains return, water may rise to the surface and potentially hazardous ponds may reappear.

With the closure of Kesterson Reservoir, an estimated 1,283 acres of wetlands were lost. In early 1990, the Regional Water Quality Control Board approved a plan to acquire and manage seven private parcels of land totalling 23,000 acres in the northern San Joaquin Drainage Basin for waterfowl and upland habitat. The land purchases would protect 6,239 acres of existing wetlands and create an additional 4,464 acres of new wetlands, resulting in a tripling of the area's wetlands acreage. The estimated 62,000 acre-feet of water required annually to manage the wetlands will come from the Central Valley Project and existing water resources associated with the land. By the summer of 1991, three of the major land parcels had been acquired.

Difficulties with selenium and other toxic trace elements are not limited to drainage water from Westlands. Some scientists and conservationists now recognize that Kesterson is only the tip of an iceberg. Comparable concentrations of selenium were detected in drainage water in nearby Grasslands Water District. Concentrations exceeding the U.S. Environmental Protection Agency's five mg/l selenium limit for freshwater aquatic systems have been measured in portions of the San Joaquin River.

The USFWS has documented waterfowl embryo deformities at four of five evaporation ponds studies in the Tulare Lake Basin. High levels of selenium also have been found in birds in the southern portion of San Francisco Bay and Suisun Bay. And, as mentioned in previous pages, the Salton Sea has been targeted as a possible selenium hot spot. Just how widespread environmental problems stemming from selenium and other trace elements are throughout the West is the subject of extensive investigation by the U.S. Department of Interior.

What is Being Done?

State and Federal Efforts

The San Joaquin Valley Drainage Program (SJVDP) was created in mid-1984 to identify the magnitude and sources of the drainage problem on the western side of the San Joaquin Valley, the toxic effects of selenium and other substances of concern to wildlife and the actions necessary to resolve the problems. The data collection and research, which was conducted by five principal participating agencies (U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Geological Survey, California Department of Fish and Game, and California Department of Water Resources), was directed at problem analysis and plan formulation concerning the effects of drainage on agricultural productivity, fish and wildlife resources, water quality and public health. The program also coordinated with the Kesterson Program and the University of California Salinity/Drainage Task Force and was advised by the National Research Council's Committee on Irrigation-Induced Water Quality Problems.

A final report issued in September 1990, entitled "A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley," focuses on in-valley management of drainage and drainage-related problems from 1990 to 2040. The report states that if the recommended action is taken, a salt balance in the plant root zone could be maintained so that physically removing salt from the valley wouldn't be necessary for several decades. The plan's principal recommendations are:

A) **Source control:** on-farm improvements in irrigation to reduce the amount of applied water.

B) **Drainage reuse:** reusing drainage water to irrigate increasingly salt-tolerant plants, thus reducing the volume of drainage water through evapotranspiration.

C) **Evaporation systems:** disposing of residual drainage water in various types of redesigned evaporation ponds.

D) **Land retirement:** fallowing farmland which overlies difficult-to-drain, shallow ground water containing high levels of selenium.

E) **Ground water management:** pumping from specified areas in the semi-confined aquifer in order to lower high water tables.

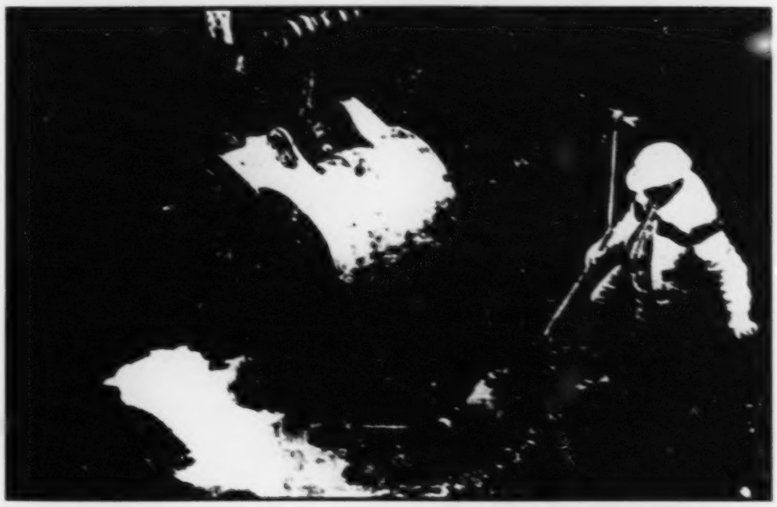
F) **Discharge to San Joaquin River:** limiting drainage discharge into the San Joaquin River while meeting water-quality objectives.

G) **Protection, restoration and water supplies for fish and wildlife habitat:** providing fresh water to substitute for drainage-contaminated supplies, protecting and restoring contaminated fisheries and wildlife habitat.

H) **Institutional change:** including tiered water pricing, improved scheduling for water deliveries, water transfers and marketing and other measures.

The report concludes that if no comprehensive drainage management plan is carried out, over the next 50 years about 554,000 acres of irrigated land in the San Joaquin Valley will have to be abandoned or converted to noncrop uses due to soil salination. The result would be a loss of $440 million per year in agricultural production and $63 million per year in retail sales for valley communities. Overall, 9,200 agriculture-related jobs would be lost by 2040. The report also concluded that by 2040, the valley's seasonal and permanent wetlands with firm water supplies would be reduced to 55,000 acres. (Currently, there are 85,000 acres to 90,000 acres of wetlands in the valley.) This would cause the concentration and decline of resident wildlife species and increase the incidence of avarian diseases.

The SJVDP devised a multiple-use plan to collect drainage water from salt-sensitive crops and use it to irrigate more salt-tolerant crops, such as cotton and barley. Drainage water from the salt-tolerant crops — approximately one-tenth the volume of



Excavation to plug subsurface drains at Westlands Water District in 1986.

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Salt crust on a cotton field in the San Joaquin Valley.

the original canal diversion and 23 times more saline — is then collected and used for a third time to irrigate even more salt-tolerant plants such as eucalyptus trees, which transpire about five acre-feet of water per acre, per year.

The tree crop could eventually be harvested and sold for fuel, and in the interim, could provide wildlife habitat as long as no environmental risk from concentrations of selenium or other trace elements is found. Drainage water from the tree crop would be reused a fourth time on atriplex, a highly salt-tolerant hay crop, and then sent to an evaporation pond for further volume reduction prior to disposal. According to the report, drainage water could be reduced by 80 percent to 95 percent through these reuse methods, thus eliminating the need for large, environmentally damaging evaporation ponds.

The primary disposal site for drainage would still be in evaporation ponds under the plan, but ponds would be redesigned to improve their safety and efficiency with steeper sides and greater depth to discourage wildlife use and vegetation growth. Other nontoxic ponds would be located nearby to provide alternative habitat. Some ponds, called "accelerated rate" ponds, would have mechanical devices installed to increase evaporation and small, solar ponds would be used only for very concentrated drainage. Highly-saline drainage water from the tree crop could be used to generate income-producing energy from **solar ponds** or **cogeneration** facilities.

Many technical, economic and institutional uncertainties remain to be resolved along the path toward implementation of a multiple-use process in California agriculture, however. For example, salt-tolerant crops generally produce less income per acre than more salt-sensitive crops. How would program-related impacts on growers' income be fairly managed if cropping patterns are altered to establish a multiple-use system? What legal and institutional tools exist to encourage growers to coordinate their crop selection, irrigation and drainage operations? How can the costs associated with multiple use be evenly shared?

According to the report, the plan "should be considered as a framework that will permit the present level of agricultural development in the valley to continue, while protecting fish and wildlife and helping to restore their habitat to levels existing before direct impact by contaminated drainage water. It is noteworthy that many of the valley's water and drainage districts and individual growers have already begun to take action similar to those recommended in this report."

Although the drainage program officially ended Sept. 30, 1990, an interagency task force consisting of four federal agencies and four state agencies is developing a procedure to implement and fund the $42 million plan. The participating agencies are also working to continue and improve monitoring of valley ground water levels, soil salt content, surface water trace element contents and fish and wildlife conditions. An implementation report is due to be published in late 1991.

Other programs that will be addressing the drainage problem are: 1) the San Joaquin Valley Management Program, a state program established in 1990 to coordinate federal, state and local efforts to manage and rehabilitate the river system, looking at issues relating to water supply, water quality, flood protection, fisheries, wildlife habitat and recreation; 2) the San Joaquin Basin Resources Management Initiative, a Bureau program to improve the water-related environment of the San Joaquin Basin with particular emphasis on chinook salmon, water quality, wetlands, wildlife and reservoir fisheries and recreation; and 3) the National Water Quality Assessment Program, a U.S. Geological Survey program to assess the quality of America's surface and ground water resources. The San Joaquin-Tulare basins form one of 20 initial hydrologic study units for the program.

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DWR operated a demonstration desalination plant at Los Banos from the fall of 1983 to August 1986. The plant, which used the **reverse osmosis** (RO) process, treated 340,000 gallons of saline drainage water per day coming from the San Luis Drain. The facility allowed for the evaluation of several pretreatment processes, such as marsh ponds to naturally filter salts from drainage water or various types of manufactured filters. The RO unit was then intended to separate water from salts, selenium and other trace elements by employing a membrane through which only water could pass. Pretreatment is necessary to prevent RO membranes from fouling from the high level of organics in drainage water. The project had only limited success in removing selenium, however, and when the San Luis Drain was closed in 1986, so was the desalination facility. While the SJVDP encourages further research into selenium-removal technology, treatment with available technology is not recommended in the action plan.

The University of California's Salinity/Drainage Task Force was established to develop, interpret and disseminate research knowledge addressing salinity, drainage, selenium and other toxic element problems in the San Joaquin Valley. In addition to funding needed research through a competitive grant process, the Task Force works closely with federal and state regulatory and research groups, publishes reports on important issues and provides the public with annual progress reports of technical work underway in the state's university system. In-field selenium reduction studies are being conducted at laboratories at the University of California, Riverside, test plots at Kesterson Reservoir and privately-owned evaporation ponds near Mendota. Soil scientists are finding ways to accelerate the **volatilization** of selenium by adding substances such as orange peels or cottonseed meal to soil. Chemical reactions between the substance and selenium cause an increase in the rate at which selenium transforms from a solid to a gas. Eventually soil scientists hope to discover a means to vent selenium to the atmosphere at a rate fast enough to make possible the restoration of Kesterson Reservoir and other selenium-contaminated soils. Selenium venting to the atmosphere is not expected to cause environmental or public health problems because of the enormous dilution which will occur when selenium gas mixes with the air. However, up-welling ground water may continue to supply the surface soils with selenium, frustrating the effectiveness of the volatilization process. Funding for this research comes from a grant from the University of California Salinity/Drainage Task Force, a grant from the U.S. Environmental Protection Agency (administered by the State Board), and the Bureau.

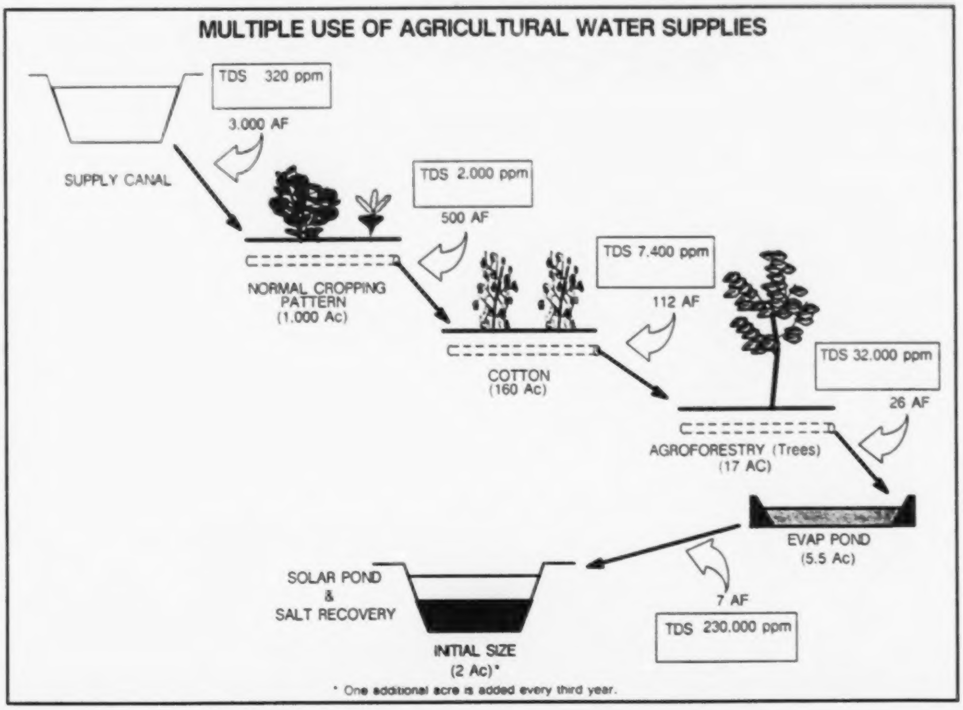
MULTIPLE USE OF AGRICULTURAL WATER SUPPLIES
TDS 320 ppm
3,000 AF
SUPPLY CANAL
TDS 2,000 ppm
500 AF
NORMAL CROPPING PATTERN (1,000 Ac)
TDS 7,400 ppm
112 AF
COTTON (160 Ac)
TDS 32,000 ppm
26 AF
AGROFORESTRY (Trees) (17 AC)
EVAP POND (5.5 Ac)
7 AF
TDS 230,000 ppm
SOLAR POND & SALT RECOVERY
INITIAL SIZE (2 Ac)*
* One additional acre is added every third year.

Diagram of a multiple water use program devised by the San Joaquin Valley Drainage Program which maximizes the beneficial use of irrigation water and minimizes the management costs, volume and harmful effects of drainage effluent.

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District Programs

Over the past decade, water districts on the west side of the San Joaquin Valley have spent millions of dollars on programs to reduce and manage the volume of agricultural drainage water produced in the valley. The 150,000-acre Central California Irrigation District and many other districts have initiated technical assistance programs aimed at improving the grower's ability to efficiently apply irrigation water, reducing the volume of drainage water created. Districts also provide low-interest loans and per-acre reimbursements so that farmers can more easily afford to upgrade their on-farm irrigation systems and prevent spills, leaks, and over-watering which contribute to excess drainage. Panoche Water District is improving irrigation scheduling to increase water transportation efficiency and minimize losses which add to drainage problems.

As a result of an agreement with the Department of the Interior, Westlands has plugged 42,000 acres of subsurface drains since June 30, 1986. Westlands farmers no longer discharge drainage water by blending it with fresh water. The district sponsors several significant drainage management, treatment and disposal programs and encourages water conservation to reduce drainage at its source. The conservation programs include weekly, crop-specific irrigation guides, periodic water management workshops, regular monitoring by the district of crop water-use and the availability of technical assistance from district staff.

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Field surveys have identified nearly 2,500 miles of unlined ditches and about 900 acres of tailwater ponds and reservoirs in the Westlands service area. Studies indicate that district-wide seepage from these facilities contribute about 27,000 acre-feet of seepage per year — 2.2 percent of the district's total applied water — to the shallow water table. The district is also in the process of locating subsurface stream channels originating in the Coast Range and determining if they are contributing runoff water to the valley's drainage problem. The first phase looked at the Panoche Fan area, an alluvial fan stretching from the Coast Range foothills east to the San Joaquin River at Firebaugh. Studies indicate that the area's soils have minimal capacity to conduct subsurface shallow ground water laterally, but research is continuing to determine the effects of upslope pumping on downslope lands.

Westlands has explored the technical and economic feasibility of using a biological treatment process to remove selenium and other trace elements from drainage water. The district is also experimenting with using plantations of salt-tolerant trees and bushes to reduce drainage through reuse and disposing of drainage water by injecting it deep into underground saline strata. In June 1989, Westlands drilled a well 8,100 feet deep intending to inject up to 1 million gallons of drainage water a day. But the project was placed on hold when tests indicated that the sandstone strata was much denser than anticipated and injection rates much slower.

Partial funding for construction and operation of the deep well injection demonstration facility ($1.1 million out of a total cost of $2.1 million) was provided by the State Board's Agricultural Drainage Loan Program, established in 1986 with passage of the Water Conservation and Quality Bond Law. Two other projects funded by the loan program include $100,000 to Panoche Drainage District for a pilot-level study to assess the feasibility of using iron fillings to remove selenium from agricultural drainage water and $1 million to Tulare Lake Drainage District to design and construct a 715-acre evaporation pond with fewer of the environmental problems which generally occur when drainage water is concentrated. To date, the State Board has provided approximately $71.25 million in loans to public agencies, made available through the bond law. As of August 1991, all available funds had been committed and renewed funding was being sought.

An option that may hold promise for the removal of selenium from drainage water is the combination of a drainage water treatment process with an electrical cogeneration facility. The process simply uses the waste heat from the natural gas turbines to evaporate untreated drainage water, leaving behind a slurry of thick salty water and solids. Developers propose to remove the selenium before the slurry residue is crystallized. Electricity generated by the turbines and fresh water condensed from the evaporation process could be used or sold to help defray costs. A 1990 Westlands report cautions, however, that disposing of the solid wastes generated by this process will be very costly.

The Future

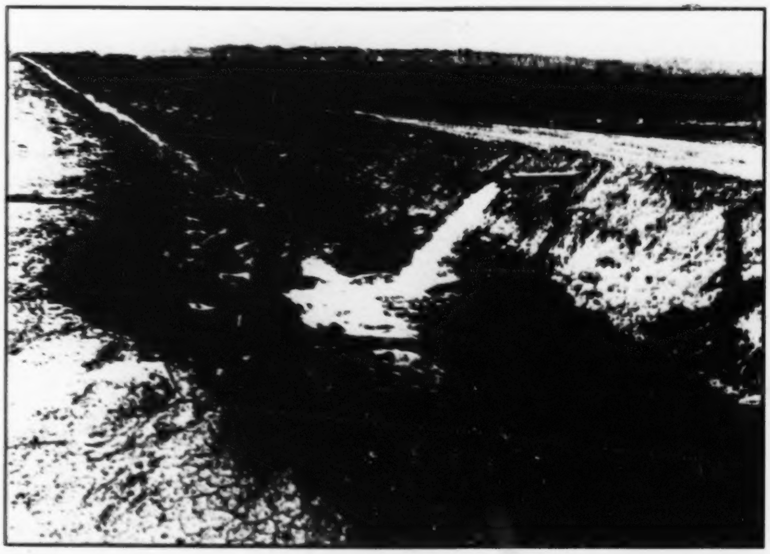
Irrigated agriculture changed the face of California forever. Since the introduction of irrigation in the mid-nineteenth century, hundreds of thousands of acres of desert and semi-arid land have been replaced by cropland and pasture. Agriculture has become an indispensable part of the state's economy. Large agricultural water appropriations and diversions have altered the natural landscape and aquatic structure of the state.

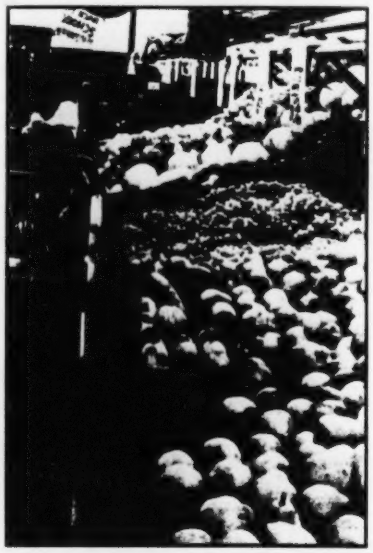
But this prosperity comes with a price. Despite multi-billion-dollar productivity, environmental dilemmas like Kesterson have caused some to view irrigated agriculture with distrust. At the same time, few would dispute California's tremendous reliance on irrigated agriculture for its economic well-being, or that agricultural productivity would be reduced without both irrigation and drainage systems. As the state's population increases, so does the need for food, fiber, clean water and employment. The most significant questions we must answer are, how can the unhealthful elements that concentrate within the drainage water be safely managed, while conserving the water at a reasonable cost, and providing food and fiber for the nation and jobs for Californians? What trade-offs will need to be made?

Everyone has a stake, of course, not only in California's agriculture, economy and environment, but also in the state's water supply future. Agriculture plays an important part in that water future, since farming uses about 80 percent of the state's developed water. As the state's population grows, competition for water for use in other sectors — urban, wetland, instream fishery, recreation — also grows. Satisfying some of these needs undoubtedly will fall upon agriculture. Recycled drainage water may play an important role in that future.

At the same time, farmers will be called upon to become increasingly flexible and adaptable. The explanation that, "We've always done it that way," will no longer be acceptable. Finding solutions to the state's drainage problems may change not only the way crops are grown, but where and which crops are grown. Emphasis on minimizing the volume of drainage water produced will encourage the use of state-of-the-art irrigation water application systems previously considered to be too expensive. New strains of salt-tolerant crops may be bred. And the identification of income-producing methods for treating or disposing of drainage water will continue to be discussed in the board rooms of water districts and in the halls of universities and environmental offices.

Solutions will be increasingly innovative and new alliances may be formed among growers to manage drainage water at the lowest possible cost. Per-acre surcharges, or otherwise increased water prices, may become necessary to cover the added cost of drainage water treatment or disposal. New agreements to supply water to the meager acreage of remaining wetlands so vital to the survival of migratory birds and waterfowl will be negotiated as the precedent for supplying wildlife habitat with drainage water is broken. Undoubtedly, some of our most precious resources — productive soils, healthy plant and animal life, safe water supplies — are at stake. The decisions we make now will affect these resources far into the future, and possibly permanently. Creativity, cooperation, compromise and vision are needed to restore and protect our environment and continue to produce the agricultural products that sustain the state and nation.





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EVALUATION FORM

As a teacher, former teacher or education specialist, we feel your comments and criticisms regarding the material's appropriateness for teacher and student use would be valuable to us. Would you be good enough to review the text and activities and give us your evaluation of them from the standpoint of the following criteria:

Readability - Are the reading and student worksheets commensurate with the reading abilities of the designated level?

____

____

Ease of Use - Are the lessons designed so that teachers and students can easily accommodate the activities within the classroom setting and in the designated subject area?

____

____

Quality - Do the lessons include concepts, knowledge and problems which are significant in promoting personal responsibility in students for conservation and wise use of a precious resource?

____

____

Defects - What shortcomings do you feel exist in the materials as presently drafted? How could these be corrected? What needs to be added?

____

____

Other Comments and Suggestions - Please note any other criticisms or comments you may have.

____

The mission of the Water Education Foundation, an unbiased, nonprofit organization, is to develop and implement education programs leading to a broader understanding of water issues and to resolution of water problems.

BIOGRAPHICAL INFORMATION

Name____

Are you a: ________Teacher

________Former Teacher

________Education Specialist

Subject area major: ________Science

________English

________Social Studies

________Math

________Other (specify)

Grade levels taught: ________K-3

________4-6

________7-9

________10-12

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CLASSROOM MATERIALS

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Classroom Materials

Water has become one of the hottest political and scientific issues in California. If our students, who are our future citizens and voters, are to make intelligent decisions about the fate of our water, they must be taught not only the scientific facts about water, but the skills necessary for gathering and evaluating information. They must also be given the opportunity to practice problem solving strategies on real-life environmental issues.

All Water Education Foundation classroom materials have been developed with the aid of grants from the Department of Water Resources and the California Department of Education's Environmental License Plate Grant Program. The goals of the programs are consistent with those of the California State Frameworks for Science and History/Social Science.

The program sets include lesson plan booklets with worksheets and evaluation devices which may be duplicated. Also included are thorough teacher instructions and background materials for teachers. Since none of the components of the units are consumable, Water Education Foundation classroom materials may be used year after year, making them a wise education investment.

The California Water Story

An upper elementary unit of study to accompany the California Water Map.

For use in grades 4-6

Goals: To teach students:

- the importance of water as a natural resource
- how California's water supply relates to its geography
- the nature of the hydrologic cycle
- the place of water in California's history
- the importance of water to California's economy
- how water is used and transported throughout the state
- the importance of conserving water
- how to protect the quality of water

Materials included in this unit:

Lesson plans with worksheets/tests
California Water Map
Layperson's guide to California Water
Water Trivia Fact Card
Hydrologic Cycle poster
Filmstrip and tape: "The California Water Story"
Water Awareness stickers

The California Water Story is a multidisciplinary approach to teaching about water as one of California's most important resources. The lessons integrate many subject areas (geography, history, science, math and art) and are designed to help students develop specific skills (critical thinking, organizing data, predicting, mapping, and graphing).

CLASSROOM SET PRICE: $15

California's Water Problems

Ideal for either a social science class studying management of natural resources or a science class studying the interaction of man and the environment.

For use in grades 6-9

Goals: To teach students:

- the relationship between geography and water distribution in California
- that water is a resource for all the people of California and must be managed for the benefit of all
- that decisions about the environment are difficult and that many viewpoints and interests must be considered
- about the variety of agencies that have some control over California's natural resources
- the danger water toxins pose for the state's water supply
- the relationship of ground water and surface water
- agricultural and urban water needs

Materials included in this unit:

Lesson plan book
California Water Map
Layperson's Guide to the Delta
Layperson's Guide to Agricultural Drainage
Layperson's Guide to the Colorado River

California's Water Problems is a series of three role-playing scenarios designed to give students first-hand experience trying to work out a solution to a real-life problem involving the management of California's water. These cooperative learning exercises give students the opportunity to develop research techniques, practice group interaction skills, and sharpen their reasoning abilities. The problems are ones that all Californians should be concerned about: protecting the Delta, preventing toxic accumulation of salts and minerals in agricultural soils, and meeting the water needs of growing urban and agricultural communities in the south part of our state. This unit is ideal for either a social science class studying management of natural resources or a science class studying the interaction of man and the environment.

CLASSROOM SET PRICE: $15

Project Water Science

A general science unit for the study of the chemistry of water and how water relates to the environment

For use in grades 7-12

Goals: To teach students:

- the importance of monitoring water quality
- the relationship of rainfall patterns to geography
- sampling techniques for testing water temperature and clarity
- the interaction of toxics in water and the ecosystem
- the importance of dissolved gases in water
- how to develop a plan for water conservation

Materials included in this unit:

Lesson plan book with lab sheets
California Water Map
Water Trivia Fact Card
Layperson's Guide to Drinking Water

Project Water Science is a series of 10 laboratory exercises suitable for junior high science or high school classes in either physical or earth sciences. The labs explore the chemical nature of water, as well as the relationship of water to ecosystems.

CLASSROOM SET PRICE: $15

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School Programs

"The California Water Story'		
Upper Elementary	$15.00/set	________
Includes:		
Lesson plans with worksheets/tests		
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Layperson's Guide to California Water		
Water Trivia Fact Card		
Hydrologic Cycle poster		
Filmstrip and tape		
Water Awareness stickers		
"California's Water Problems"		
Middle school level *(Role-Playing Strategy)*	$15.00/set	________
Includes:		
Lesson plan book		
California Water Map		
Layperson's Guide to the Delta		
Layperson's Guide to Agricultural Drainage		
Layperson's Guide to the Colorado River		
"Project Water Science"		
Secondary level	$15.00/set	________
Includes:		
Lesson plan book with lab sheet		
California Water Map		
Water Trivia Fact Card		
Layperson's Guide to Drinking Water		

Other items

Water Awareness Guide: "Where Your Water Comes From"	$3.00 each	________
California Water Map	$7.50 each	________
Colorado River Water Map	$8.50 each	
Hydrologic Cycle Poster	$3.00 each	________
Water Trivia Fact Card	$1.00 each	________
Layperson's Guide	$3.50 each	________
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